BERGEY'S MANUAL
OF
DETERMINATIVE BACTERIOLOGY

BY

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PREFACE TO SIXTH EDITION

More than the usual amount of time and effort has been given toward making this new edition of Bergey's Manual useful. The volume has been completely revised and is reset in double column format so that each page carries about 20 per cent more type than the pages in the fifth edition. Those who are interested in special groups of bacteria will find something new in the presentation of the relationships in every genus. Because of our rapidly expanding knowledge, changes in the outline classification and text were made necessary. These changes have in every case been made by specialists in consultation with the Editorial Board. Every specialist possesses first hand knowledge of the species in the group that he or she has reviewed.

Because increasing knowledge has shown the fission fungi to be a larger and more diversified group than previously realized, the number of species described has increased from 1335 in the fifth edition to 1630 in the present edition of the Manual. This number does not cover all of the descriptions found in the literature for, as in all other fields of biology, many of the descriptions are so inadequate that the species described cannot now be identified. Many descriptions are obvious or probable duplications of previous descriptions while still others are based on nothing more substantial than the author's belief that he had something new, he having made but little effort to compare his cultures with those found by previous investigators. An indication of the large number of inadequate descriptions will be found by referring to the material in the appendixes to the various groups, and to the index where synonyms and incompletely described species are shown in italics.

The large number of these poorly described species suggests that there has been much unsatisfactory work done in the field of bacteriological taxonomy. Progress in this inadequately developed field is needed as it would help to clarify the approach to desirable research in many fields of bacteriology.

It is believed that both teachers and investigators will find the new Source and Habitat index useful. It is important to know what organisms have been described from any given habitat in determining the identity of a described species or whether a given species is new.

The future development of taxonomic work holds several interesting possibilities of increased international cooperation such as between the various National Type Culture Collections and within the International

Association of Microbiologists. The Trust Funds provided through the generosity of Dr. Bergey before his death have been used in developing the present edition of the Manual and future funds are to be used in the same way under the management of a self-perpetuating Board of Editor-Trustees.

We are all under obligation to those who have given so freely of their time and special knowledge in preparing this edition of the Manual. Moreover the Editor-in-Chief is under special obligation to his wife, Margaret Edson Breed who has carried the burden of the indexing; to Mrs. Eleanore Heist Clise who has given invaluable service in bibliographical research, in proof reading and other ways; and to his secretary, Miss Maude Hogan, who has cared for many difficult manuscripts and a voluminous technical correspondence.

Many binomials not previously mentioned in the Manual will be found in the Index of Genus and Species Names. Each new name means that there is a new bibliographic reference in the text. Practically all of the incomplete references of previous editions and all new references have been examined in the original, something that is essential in all accurate taxonomic work. The index of names is the most complete list that has appeared in the literature and should always be consulted before new genus or species names are proposed.

This edition of the Manual has been more than four years in press, thanks to the care that has been taken to make it complete and useful. Throughout, the Editorial Board has had the cooperation and understanding help of the publishers of the book who themselves have been forced to meet and overcome the trying difficulties of the war years.

The plan of the present book is such that it will be found useful both to teachers and research workers.

Robert S. Breed, *Chairman*
E. G. D. Murray
A. Parker Hitchens
Board of Editor-Trustees.

April, 1947.

PREFACE OF FIRST EDITION

The elaborate system of classification of the bacteria into families, tribes and genera by a Committee on Characterization and Classification of the Society of American Bacteriologists (1917, 1920) has made it very desirable to be able to place in the hands of students a more detailed key for the identification of species than any that is available at present. The valuable book on "Determinative Bacteriology" by Professor F. D. Chester, published in 1901, is now of very little assistance to the student, and all previous classifications are of still less value, especially as earlier systems of classification were based entirely on morphologic characters.

It is hoped that this manual will serve to stimulate efforts to perfect the classification of bacteria, especially by emphasizing the valuable features as well as the weaker points in the new system which the Committee of the Society of American Bacteriologists has promulgated. The Committee does not regard the classification of species offered here as in any sense final, but merely a progress report leading to more satisfactory classification in the future.

The Committee desires to express its appreciation and thanks to those members of the society who gave valuable aid in the compilation of material and the classification of certain species. . . .

The assistance of all bacteriologists is earnestly solicited in the correction of possible errors in the text; in the collection of descriptions of all bacteria that may have been omitted from the text; in supplying more detailed descriptions of such organisms as are described incompletely; and in furnishing complete descriptions of new organisms that may be discovered, or in directing the attention of the Committee to publications of such newly described bacteria.

DAVID H. BERGEY, *Chairman*
FRANCIS C. HARRISON
ROBERT S. BREED
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FRANK M. HUNTOON
Committee on Manual.

August, 1923.

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INTRODUCTION

Suggestions for the Use of the Manual in Classifying Unknown Organisms

No organism can be classified before we have determined, through detailed study, its morphological, cultural, physiological and pathogenic characters.

The characters used in the keys to orders, families and genera may ordinarily be determined by the use of a dozen or more of the procedures described in the Manual of Pure Culture Study issued by the Committee on Bacteriological Technic (H. J. Conn, Chairman, Geneva, New York) of the Society of American Bacteriologists. More complete examinations must be made as indicated in the Manual of Pure Culture Study, and in the Descriptive Charts which accompany this Manual where it is desired to identify individual species. These tests must be made if bacteria are to be accurately identified and described.

It is urged that beginning students be taught the technics necessary for the identification of species in the hope that the taxonomic work of the future may be placed on a more satisfactory basis.

After a complete study of the characters of the organism has been made, turn to page 65 and ascertain first in which order the organism belongs. When the order and suborder (if necessary) have been ascertained, turn to the page of the Manual on which the key to that order or suborder is given. In this key ascertain the family or subfamily to which the organism belongs.

When the family or subfamily has been decided on, again refer to the page of the Manual on which the key to that family or subfamily is given. In this key ascertain the tribe to which the organism belongs.

When the tribe has been decided on, again find the page of the Manual on which the key to the tribe is given. In this key ascertain the genus to which the organism belongs.

When the genus has been decided on, again refer to the page of the Manual on which the key to that genus is given. In this key, trace out the species under investigation.

For example, if one wishes to trace a short, peritrichous, Gram-negative, non-spore-forming rod that grows well on ordinary culture media at 37°C, fermenting glucose and lactose with production of acid and gas, not liquefying gelatin, producing no pigment on any culture medium, with negative reaction for acetylmethylcarbinol, producing indole and reducing nitrates, consult the key to the orders on page 65.

In this key examine A. *Cells rigid, not flexuous.* This indicates our organism as its cells remain constant in form.

We next examine 1. *Cells single, in chains or masses. Not branching and mycelial in character. Not arranged in filaments. Not acid fast.* As the organism in question occurs as single cells or at most as short chains and is not acid fast, this indicates that it belongs to the Order *Eubacteriales.*

We now examine a. *Do not possess photosynthetic pigments. Cells do not contain free sulfur.* As our organism is unpigmented and the cells do not contain free sulfur, this indicates that our organism belongs to the Sub-order *Eubacteriineae.* We note that the key to this suborder is on page 67.

We next attempt to ascertain the family to which the organism belongs by tracing it through the key to the families of the Sub-order *Eubacteriineae,* p. 67.

I. *No endospores* indicates our organism. We proceed to A. *Can develop on inorganic media.* As the organism cannot grow without organic carbon, we turn to B. *Cannot develop on inorganic media.*

This corresponds with the physiology of our organism; so we turn to 1. *Polar flagellate,* etc. As our organism is peritrichous, we proceed to 2. *Large oval, pleomorphic cells sometimes almost yeast-like in appearance. Free living in soil. Fix free nitrogen.* As this does not correspond with the morphology or physiology of our organism, we next examine 3. *Peritrichous or non-motile rods, and cocci.* This corresponds with the characteristics of our organism.

We turn to a. *Heterotrophic rods which may not require organic nitrogen for growth. Usually motile with one to six or more flagella. Usually form nodules or tubercles on roots of plants, or show violet chromogenesis.*

This again does not indicate our organism; so we turn next to aa. *Heterotrophic rods or cocci which utilize organic nitrogen and usually carbohydrates.* As our rod-shaped organism prefers a medium containing organic nitrogen, we proceed to b. *Spherical cells in masses, tetrads and packets.*

This does not correspond to the morphology of our organism, and we now proceed to bb. *Spherical cells which grow in pairs and chains; and rods.* This includes our rod-shaped organism; so we turn to c. *Gram-positive cocci and rods. Non-motile.* Since these are not the characteristics of our organism, we turn to cc. *Gram-negative rods. When motile, from four to many peritrichous flagella.*

Our organism is Gram-negative and peritrichous; so we proceed to d. *Grow well on ordinary media containing peptone. Aerobic to facultative anaerobic.*

This corresponds with the characteristics of the organism we have studied; so we turn next to e. *Gram-negative, straight rods which ferment*

sugars with the formation of organic acids. This again corresponds with our organism. We turn next to f. *Produce little or no acid from litmus milk.* This does not correspond with the characters we have determined for our organism. We proceed to ff. *Produce CO_2 and frequently visible gas (CO_2 + H_2) from glucose. Reduce nitrates, etc.*

Our organism produces visible gas from glucose and reduces nitrates. This indicates that it belongs to *Family X. Enterobacteriaceae*, p. 443.

This appears to fit our unknown organism. We now refer to page 443 on which the key to the Family *Enterobacteriaceae* is found. In this key we ascertain the Tribe to which our organism belongs. 1. *Ferment glucose and lactose with the formation of acid and visible gas. Usually do not liquefy gelatin. Tribe I. Eschericheae.*

This corresponds with the characters exhibited by our organism. We refer to the key for Tribe I. *Eschericheae* on the same page. 1. *Methyl red test positive. Voges-Proskauer test negative. Salts of citric acid may or may not be used as sole source of carbon. Genus I. Escherichia*, p. 444.

This description appears to correspond with that of our unknown organism. We find the key to the species of Genus *Escherichia* follows the key to the Tribe *Eschericheae.* On tracing our organism in this key we find that it corresponds to *Escherichia coli.* A brief description of this organism is found on the same page.

* In the use of keys for identifying bacteria, the student is confronted with two difficulties, both based primarily on lack of knowledge and experience. The first is insufficient knowledge concerning the morphology, physiology, possible pathogenicity and habitat of the microorganisms that are to be identified. This may be due to careless observations or to poor training in the special techniques that must be used in determining the identity of a given bacterium.

The second difficulty in the use of a key comes from inexperience in the use of technical terms; that is, the student may not thoroughly understand the meaning of the statement in the key and so cannot follow a route through the key with certainty. For example in the keys used here, the student must know the difference (1) between chains of cells which are composed of dividing cells which do not separate at once, and (2) filaments which are composed of dividing cells which remain more permanently together and are normally flattened against each other on adjacent sides. They may show some differentiation into hold fast cells and reproductive cells (conidia), (3) Both chains of cells and filaments are to be distinguished from the mycelial threads found in *Actinomycetaceae.* These are unseptate and branching with a true branching.

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* Condensed and paraphrased from Hitchcock's Descriptive Systematic Botany, New York, 1935.

The student should be warned not to take descriptions in the MANUAL too literally or too rigidly. Descriptions are usually drawn to represent average findings. Especially among bacteria, characters such as sugar fermentations, gelatin liquefaction, presence or absence of flagella and other things will vary. Sometimes these variations are due to slight, possibly unrecognized variations in the techniques used in determining these characters. Real knowledge of the characteristics of species may also be very incomplete. This is true not only of the physiological activities of these microorganisms; but also in regard to such detectable structural features as the number and position of flagella. Dark field movies of motile cells and photographs taken with the recently developed electron microscope are revealing new and heretofore unsuspected facts regarding structural features.

Source and habitat data are frequently helpful in aiding the student to recognize species of bacteria and may indicate that the pathogenicity of the culture in question may need to be tried on some specific animal or plant. By habitat is meant the kind of a place in which the organism normally grows; by source, the particular material and place from which the culture was obtained. This source may or may not indicate the natural habitat. The source of cultures is invariably more limited in scope than the habitat as bacteria normally occur wherever their particular habitat may be found in a world wide distribution.

The student is also reminded that it is impracticable to note all exceptions in keys. Bacteria like other living things are classified according to a combination of characters, not according to some single character, and exceptions to the characters noted in the keys will occur in nature. These may not be known to or may have been overlooked by the author of the key. On the other hand, the importance of such exceptions should not be overemphasized and the student would do well to use the key as if there were no exceptions.

HISTORICAL SURVEY OF CLASSIFICATIONS OF BACTERIA, WITH EMPHASIS ON OUTLINES PROPOSED SINCE 1923*

There have been numerous attempts to arrange the species of bacteria in natural systems of classification. The first simple system of Müller (Vermium terrestrium et fluviatilium, 1773) which he developed further a few years later (Animalcula infusoria fluviatilia et marina, 1786) listed but two genera (*Vibrio* and *Monas*) that included organisms that would today probably be accepted as bacteria. *Polyangium* Link (Mag. d. Ges. Naturforsch. Freunde zu Berlin, *3*, 1809, 42) is apparently the oldest of the generic terms retained in its original meaning for a bacterial genus while *Serratia* Bizio (Biblioteca italiana o sia giornale de lettera, scienze ed arti, *30*, 1823, 288) was proposed only fourteen years later.

Systems of classification developed after 1773 are given in complete outline form in the first edition of the MANUAL (1923) and this section of the MANUAL was reprinted without material change in the second (1925) and third (1930) editions. While it is not felt to be necessary to repeat these outlines in their entirety, sufficient reference is made below to permit the student to trace the origin of generic terms that are no longer commonly found in classification outlines. No attempt has been made to include reference to other little used generic terms except as they appear as synonyms in the descriptive portion of the MANUAL. For the origin of generic terms proposed before 1925, see Enlows (The Generic Names of Bacteria, Bul. No. 121, Hygienic Laboratory, Washington, D. C., 1920) and Buchanan (General Systematic Bacteriology, Baltimore, 1925).

Bory St. Vincent (Microscopiques, Dictionnaire classique d'histoire naturelle, *10*, 1826, 533) introduced the generic terms *Spirilina*, *Melanella*, *Lactrimatoria* and *Pupella* and accepted *Vibrio* for microorganisms, some of which must have been bacteria. None of these terms, except *Vibrio*, are in current use for bacterial groups.

Three of the terms accepted or proposed by Ehrenberg (Die Infusionstierchen als volkommene Organismen, Leipzig, 1838); namely, *Vibrio*, *Spirillum* and *Spirochaeta*, are still used. The generic term *Bacterium* proposed first by Ehrenberg in 1828 (Symbolae Physicae seu Icones et Descriptiones Animalium Evertebratorum Separasitis Insectis quae ex Itinere per Africam Borealem et Asiam Occidentalem, IV. Evertebrata, Berlin) to include but a single species *Bacterium triloculare* from an oasis

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* **Contributed by Prof. R. S. Breed, New York State Experiment Station, Geneva, New York, July, 1938; revised, September, 1943.**

in North Africa, has had a varied history because this type species (monotypy) is no longer identifiable. It was reintroduced into the classification employed in the fifth edition of the MANUAL to cover species of non-spore-forming rods whose positions in the outline given in the MANUAL have not yet been satisfactorily determined (Breed and Conn, Jour. Bact., *31*, 1936, 517) and is used in the present edition with the same meaning. The term *Spirodiscus* was applied by Ehrenberg to a single organism that he found in a mountain stream. It has never been reidentified and subsequent authors have discarded this term.

Two new generic terms (*Metallacter*, *Sporonema*) were introduced by Perty (Zur Kenntniss kleinster Lebensformen, 1852). Neither *Metallacter* nor *Sporonema* is in common use at the present time.

Davaine (Dictionaire encyclop. des sciences méd., Art. bactéries, 1868) introduced one new generic term, *Bacteridium*, for straight motionless rods like the anthrax bacillus.

The generic terms employed by Cohn in his first classification (Untersuchungen über Bakterien. I. Beiträge z. Biol. d. Pflanzen, *1*, Heft 2, 1872, 146) are all in current use. Only one (*Bacillus*) was new. Other generic terms were introduced into his second paper (Untersuchungen über Bakterien. II. *ibid.*, *1*, Heft 3, 1875, 141) which contained his more complete classification. For various reasons, six of these, *Merismopedia*, *Clathrocystis*, *Ascococcus*, *Myconostoc*, *Cladothrix* and *Streptothrix* are not found in recent bacteriological classifications.

Mangin (Les Bactéries, Paris, 1878) recognized three subgenera of the genus *Monas*, the first of which *Rhabdomonas* Cohn, 1875 is still used as a generic term, while the other two, *Ophidomonas* Ehrenberg, 1838 and *Spiromonas* Perty, 1852 have been dropped.

The bacterial species that had been placed in the genus *Clathrocystis* by Cohn (1875) were separated and placed in a new genus *Cohnia* by Winter (Die Pilze in Rabenhorst's Kryptogamen Flora, 1880), and this name is also used by Burrill (The Bacteria, Springfield, Ill., 1882). Because this name had previously been proposed for a genus of lilies, it was soon dropped.

Zopf (Die Spaltpilze, Leipzig, 1883) accepts *Phragmidiothrix*, a generic name suggested by Engler in 1882 for a single species found on the body of a crustacean (*Gammarus locusta*). Later authors generally either merge this genus with *Crenothrix* Cohn or disregard it because of the indefinite description of the one species included in it.

Baumgarten (Lehrbuch der pathologischen Mykologie, Braunschweig, 1890) following Hueppe accepts the term, *Spirulina*, for a genus of pleomorphic bacteria, disregarding the previous use of the term by algologists.

The generic terms found in Migula's first outline (Bakterienkunde für

Landwirte, Berlin, 1890) were those in conventional use at the time and many of them continue in use. Two new terms were introduced for motile types in his second outline (Arb. Bact. Inst. Karlsruhe, *1*, 1894, 235) and are also found in his later outlines (Engler and Prantl, Die natürlichen Pflanzenfamilien, *1*, 1a, 1895, 29, and System der Bakterien, *1*, 1897, 46, and *2*, 1900, 269 and 275) which have not been generally felt to be necessary by subsequent authors. These are *Planococcus* and *Planosarcina*. *Spirosoma* introduced by Migula in 1894 and *Rhabochromatium* Winogradsky accepted by Migula in 1900 are likewise no longer generally used. *Newskia* (original spelling *Nevskia* Famintzen, Bull. Acad. Imp. Sci., St. Petersburg, *34* (N.S. *2*), 1892, 484) has recently been revived by Henrici and Johnson (Jour. Bact., *29*, 1935, 3 and *30*, 1935, 83). The generic term *Microspira* Schroeter, accepted by Migula in 1894, is still frequently accepted in place of *Vibrio* as many regard it as having a better status than the later term.

The term *Pseudomonas* was first proposed for polar flagellate bacteria by Migula in his 1894 outline with reference to but a single species, *Pseudomonas violacea*, an organism which later investigators have shown to be peritrichous (Cruess-Callaghan and Gorman, Sci. Proc. Roy. Dublin Soc., *21*, 1935, 213). *Pseudomonas* was repeated in the 1895 outline with descriptions of *Pseudomonas pyocyanea* and other species. Later authors have generally accepted the term *Pseudomonas* as valid.

Fischer (Jahrb. f. wissensch. Bot., Berlin, *27*, 1895, 1) introduced a logical outline classification in which he proposed various new terms which have never come into general use. These are *Paracloster*, *Paraplectrum*, *Arthrobacter*, *Bactrinium*, *Clostrinium*, *Plectrinium*, *Arthrobactrinium*, *Bactrillum*, *Clostrillium*, *Plectrillium*, *Arthrobactrillium*, *Bactridium*, *Plectridium*, *Diplectridium*, and *Arthrobactridium*. In his modified classification (Vorlesungen über Bakterien, 1897), he also accepts *Pediococcus* Balcke, a term that has fallen into disuse except in the brewing industry.

In the conservative classification proposed by Lehmann and Neumann (Atlas und Grundriss der Bakteriologie, 2 vols., 1896, München), internationally accepted rules of nomenclature were followed. All of the generic terms employed by them are still in current use, their most important contribution being their acceptance of the suggestion that the genus *Bacillus* be separated from the genus *Bacterium* on the basis of endospore formation by the rods included in *Bacillus*. Two new genera were proposed (*Corynebacterium* and *Mycobacterium*) that have been generally accepted by later workers.

No new generic terms are proposed by Chester either in his preliminary reports (Delaware College of Agriculture, 9th Ann. Rept., 1897, 53 and 62;

11th Ann. Rept., 1899, 36), or in his complete outline (Manual Determ. Bact., 1901). Almost all of the generic terms found in his outlines are still in current use.

The term *Aplanobacter* suggested by Erwin F. Smith (Bacteria in Relation to Plant Diseases, *1*, 1905, 171, Washington) was accepted by certain American phytopathologists for a time but has never come into general use.

Because other differences between the non-chromogenic and chromogenic micrococci are unimportant, two generic terms, *Albococcus* and *Aurococcus*, suggested by the Winslows (Science, *21*, 1905, 669; Systematic Relationships of the Coccaceae, New York, 1908) have not come into general use. They also suggested *Rhodococcus* to include *Rhodococcus roseus* and *R. fulvus* apparently without realizing that Zopf (Ber. d. deutsch. bot. Gesellsch. Berlin, *9*, 1891, 28) had previously used the same term for *Rhodococcus erythromyxa* and *R. rhodochrous*. Hansgirg (Engler and Prantl, Die natürlichen Pflanzenfamilien, *1*, 1a, 1895, 52) had also used it previously to designate a sub-genus of the green algae, and later Molisch (Die Purpurbakterien, Jena, 1907, 20) used *Rhodococcus* for a genus of the purple bacteria to include *Rhodococcus capsulatus*.

In his complete outline of the classification of bacteria presented in 1909, Orla-Jensen (Cent. f. Bakt., II Abt., *22*, 1909, 305) introduced many new generic terms in an effort to create a nomenclature that appeared to him to express the natural relationships of bacteria more satisfactorily than names previously suggested had done. Thus he used the suffixes *coccus* and *sarcina* for spherical bacteria and *monas* for all genera known to be lophotrichous or so related to these types that they were regarded as essentially lophotrichous in nature. In the same way the suffix *bacterium* was used for genera of non-spore-forming rods. that were regarded as essentially peritrichous in nature, and the suffix *bacillus* for similar spore-forming rods. As, however, subsequent investigators have (1) accepted the priority rule, (2) felt that it was impossible to recognize the type of motility found in the ancestry of truly non-motile groups, or (3) felt that other characters were more fundamental than those selected by Orla-Jensen, many of these terms have not been generally used by later workers.

Among the little used terms suggested or accepted by Orla-Jensen are: *Acetimonas*, *Nitromonas*, *Azotomonas*, *Rhizomonas*, *Corynemonas*, *Mycomonas*, *Sulfomonas*, *Thiomonas*, *Thiococcus*, *Rhodomonas*, *Rhododictyon*, *Amoebomonas*, *Rhodopolycoccus*, *Rhodosarcina*, *Spirophyllum*, *Denitromonas*, *Liquidomonas*, *Liquidovibrio*, *Liquidococcus*, *Solidococcus*, *Solidovibrio*, *Sporosarcina*, *Denitrobacterium*, *Caseobacterium*, *Liquidobacterium*, *Urobacillus*, *Butyribacillus*, *Pectobacillus*, *Cellulobacillus*, *Putribacillus* and *Botulobacillus*.

While *Nitromonas* is not new, it is redefined as a synonym of *Nitrobacter* Winogradsky (Arch. Sci. Biol. St. Petersburg, *1*, 1892, 87), rather than as a synonym of *Nitromonas* Winogradsky (Ann. Inst. Past., *3*, 1890, 258). *Spirophyllum* is from Ellis (Cent. f. Bakt., II Abt., *19*, 1907, 507).

In a later monograph on The Lactic Acid Bacteria (Mém. d. Acad. Roy. Sci. et Lettres de Danemark, Sect. Sci., 8 Sér., *5*, 1919, No. 2) Orla-Jensen proposes the following additional generic terms: *Betacoccus*, *Betabacterium*, *Streptobacterium*, *Thermobacterium* and *Microbacterium*. The term *Tetracoccus* is introduced with a meaning different from that given the term previously by v. Klecki (Cent. f. Bakt., *15*, 1894, 354).

Buchanan prepared an outline classification in 1916 (Jour. Bact., *1*, 1916, 591; *2*, 1917, 155, 347, 603; *3*, 1918, 27, 175, 301, 403, 461, 591) which was utilized in part by the group of which he was a member (Winslow, Broadhurst, Buchanan, Krumwiede and Smith) in their preliminary Report to the Society of American Bacteriologists (Jour. Bact., *2*, 1917, 552) and in the final report by Winslow, Broadhurst, Buchanan, Krumwiede, Rogers and Smith (Jour. Bact., *5*, 1920, 191).

Although prepared earlier, some parts of the Buchanan outline were not published until after the first Winslow et al. report. As these reports formed the most important basis for the classification used in the first edition of the MANUAL, it is natural that the generic terms utilized are, in general, the same as those used in the MANUAL.

Generic and subgeneric terms included by Buchanan that are not used in the present edition of the MANUAL are: *Paraspirillum* Dobell (Arch. f. Protistenk., *24*, 1911, 97), *Eubacillus* Hansgirg (Osterr. Bot. Ztschr., *38*, 1888, 264; not *Eubacillus* Dangeard, Le Botaniste, *2*, 1891, 151) and *Metabacterium* Chatton and Perard (Comp. rend. Soc. Biol., Paris, *65*, 1913, 1232). *Siderocapsa* Molisch (Ann. Jard. Bot. Buitenzorg, Ser. 2, Supp. 3, 1909, 29) used by Buchanan but dropped by Winslow et al (Jour. Bact., *2*, 1917, 549) does not appear in the MANUAL classification outline until the present (6th) edition. The term *Mycoderma* recognized both by Buchanan (Jour. Bact., *3*, 1918, 45) and in the preliminary Winslow et al. report (Jour. Bact., *2*, 1917, 551) was replaced by the later and more valid term *Acetobacter* in the final report by Winslow et al. (Jour. Bact., *5*, 1920, 201). *Pfeifferella* Buchanan (Jour. Bact., *3*, 1918, 54) which is used in the three outline classifications under discussion and also in the first, second and third editions of the MANUAL, appeared in the literature through a clerical error (Buchanan, General Systematic Bacteriology, 1925, 420). It was combined in the fourth edition of the MANUAL with the genus *Actinobacillus* under the latter name. *Nocardia* Trevisan (1889) used by Buchanan and in the preliminary report by Winslow et al. (1917) was merged with *Actinomyces*

Harz (Jahresber. München. Thierarzneisch. for 1877–78, 125) in the final report by Winslow et al. *Erythrobacillus* Fortineau (Compt. rend. Soc. Biol. Paris, *58*, 1905, 104) is used by Winslow et al. (1920) but was not accepted in the first and following editions of the MANUAL as it is a synonym of the older *Serratia* Bizio (1823). Moreover, the species which must be accepted as type for the genus (*Erythrobacillus pyosepticus* Fortineau (monotypy)) is a species which has been reported by Breed (Manual, 3rd ed., 1930, 117) to be a variant of the older *Serratia marcescens*.

One of the most unsatisfactory portions of recent classifications, such as those outlined by Buchanan (1917–18) and by Winslow et al. (1917), is the treatment given the organisms of the coliform-dysentery-typhoid group in that the term *Bacterium* is retained for these as suggested by Orla-Jensen (1909). A strict limitation of *Bacterium* to this group gives it a still different meaning from that which it had had in previous and current classifications, and makes it necessary to find some other place for many other species of Gram-negative, non-spore-forming rods, some of which are well known and well described. The relationships of these miscellaneous species to other non-spore-forming rods is frequently poorly understood. In some cases, further study will probably show that they should be placed in well known and currently recognized genera. In others, further study will probably show that some of these species of non-spore-forming rods should be grouped in new genera.

Winslow et al. (1920) recognized this situation and broadened their definition of *Bacterium* thereby placing such well known species as are included in the colon-dysentery-typhoid group with other species of non-spore-forming rods of quite a different character. For this reason, partial use was made in the first edition of the MANUAL of the numerous generic terms newly proposed by Castellani and Chalmers (Manual of Tropical Medicine, 3rd ed., 1919). Thus the following new terms were introduced: *Alcaligenes*, *Salmonella*, *Escherichia* and *Encapsulatus;* and the earlier terms *Aerobacter* Beijerinck (1900) and *Eberthella* Buchanan (1918). Later it was found that *Encapsulatus* was a synonym of *Klebsiella* Trevisan (1887), so that the latter term was accepted in the second and subsequent editions of the MANUAL. *Shigella* Castellani and Chalmers was recognized as distinct from *Eberthella* in the third and subsequent editions.

Many of the new terms suggested by Castellani and Chalmers were, however, synonyms of earlier valid terms or have not been considered necessary, and so they have not come into general use. These are *Nigrococcus*, *Graciloides*, *Cloaca*, *Eberthus*, *Dysenteroides*, *Lankoides*, *Wesenbergus*, *Balkanella* and *Enteroides*. No new generic terms are given by Castellani and Chalmers in their later report (Ann. Inst. Past., *34*, 1920, 600).

Orla-Jensen (Jour. Bact., *6*, 1921, 263), in a paper published after the manuscript of the first edition of the Manual was prepared, suggested the use of *Colibacterium* and *Aerogenesbacterium* for the two genera in the coliform group and adds quite a number of other new terms formed in accordance with his system of nomenclature. These are, in most cases, synonyms of earlier valid names. The new terms are *Coccomonas*, *Spiromonas* (used in a new, different sense from that of earlier authors), *Fluoromonas*, *Photomonas*, *Propionicoccus*, *Butyriclostridium* and *Putriclostridium*.

Many new terms are proposed in the classification drawn up by Heller (Jour. Bact., *6*, 1921, 521; and *7*, 1922, 1). Details are given in the group of anaerobic spore-formers only. Here each of the new generic terms is based on a single species. The following outline is given in the first of these papers, two new genera (*Rivoltillus* and *Metchnikovillus*) being made the type genera for two new subfamilies *Clostridioideae* and *Putrificoideae*, respectively.

Phylum I. *Bacteria*
  Class I. *Eubacterieae*
    Order 1. *Eubacteriales*
      Family 6 (?). *Clostridiaceae*
        Subfamily 1. *Clostridioideae*
        Subfamily 2. *Putrificoideae*
    Order 2. *Thiobacteriales*
    Order 3. *Chlamydobacteriales*
  Class II. *Myxobacterieae*

In the more complete outline in the second paper, one generic term (*Clostridium*) is old, although it is used in a new and restricted sense, while with the exception of the type genera mentioned above, the other terms are new. In the subfamily *Clostridioideae*, the new terms are *Omelianskillus*, *Macintoshillus*, *Douglasillus*, *Henrillus*, *Flemingillus*, *Vallorillus*, *Multifermentans*, *Hiblerillus*, *Welchillus*, *Stoddardillus*, *Arloingillus*, *Meyerillus* and *Novillus*. Ten new generic terms are used in the subfamily *Putrificoideae* as follows: *Sequinillus*, *Reglillus*, *Robertsonillus*, *Nicollaierillus*, *Martellillus*, *Recordillus*, *Tissierillus*, *Putrificus*, *Ermengemillus*, and *Weinbergillus*. As there does not seem to be any good reason for sub-dividing the genus *Clostridium* in this way, the latter term has been used to cover anaerobic spore-forming rods in all previous editions of the MANUAL, and is again used in the present edition in this sense rather than with the restricted meaning proposed by Heller.

Enderlein (Sitzber. Gesell. Naturf. Freunde, Berlin, 1917, 309) proposed an outline classification covering the Kingdom of *Mychota*, or bacteria, which was based on comparative morphology with special emphasis on life cycles. This was as follows:

Phylum I. *Dimychota*
Kreis A. *Holocyclomorpha*
Class I. *Gonascota*
Order a. *Synascota*
Family 1. *Schaudinnidae*
Genus a. *Schaudinnum*
b. *Theciobactrum*
Family 2. *Sphaerotilidae*
Genus a. *Phragmidiothrix*
b. *Newskia*
c. *Chlamydothrix*
d. *Sphaerotilus*
e. *Clonothrix*
Family 3. *Syncrotidae*
Genus a. *Crenothrix*
b. *Beggiatoa*
c. *Syncrotis*
d. *Zygostasis*
Family 4. *Spirillidae*
Genus a. *Gallionella*
b. *Spirillum*
c. *Dicrospirillum*
Family 5. *Spirochaetidae*
Genus a. *Cristispira*
b. *Treponema*
c. *Entomospira*
d. *Spirochaeta*
e. *Cacospira*
Family 6. *Microspiridae*
Genus a. *Spirobacillus*
b. *Spirosoma*
c. *Photobacterium*
d. *Microspira*
e. *Dicrospira*
Family 7. *Corynobacteriidae*
Subfamily 1. *Actinomycinae*
Genus a. *Actinomyces*
Subfamily 2. *Eisenberginae*
Genus a. *Eisenbergia*
Subfamily 3. *Sclerotrichinae*
Genus a. *Zettnowia*
b. *Schlerothrix*
Subfamily 4. *Corynobacteriinae*
Genus a. *Corynobacterium*
b. *Heterocystia*
c. *Cladascus*
d. *Zygoplagia*
Subfamily 5. *Pseudostrepinae*
Genus a. *Pseudostreptus*
Order b. *Ascota*
Family 8. *Bacteriidae*

Genus a. *Atremis*
b. *Bacterium*
c. *Lamprella*
d. *Eucystia*
e. *Dicrobactrum*
f. *Acystia*
Family 9. *Fusiformidae*
Genus a. *Fusiformis*
Class II. *Sporascota*
Order a. *Parasynascota*
Family 10. *Migulanidae*
Genus a. *Migulanum*
Order b. *Parascota*
Family 11. *Bacillidae*
Genus a. *Rhagadascia*
b. *Plectridium*
c. *Bacillus*
d. *Bactrillum*
e. *Kochella*
f. *Fischerinum*
Kreis B. *Hemicyclomorpha*
Class I. *Anascota*
Family 12. *Hemallosidae*
Genus a. *Hemallosis*
Phylum II. *Monomychota*
Kreis A. *Acyclomorpha*
Family 1. *Mogallidae*
Genus a. *Mogallia*
Family 2. *Sarcinidae*
Genus a. *Diplococcus*
b. *Sarcina*
c. *Paulosarcina*
Family 3. *Micrococcidae*
Genus a. *Micrococcus*
b. *Planococcus*
c. *Streptococcus*
d. *Phacelium*

Three of the new generic terms, *Cladascus* type species *C. furcabilis* Enderlein, *Zygoplagia* type species *Z. alternans* Enderlein and *Heterocystia* type species *H. multiformiis* Enderlein, had been proposed in an earlier paper (Sitzber. Gesell. Naturf. Freunde, Berlin, 1916, 395). The following generic terms in the 1917 outline are new: *Schaudinnum*, *Theciobactrum*, *Syncrotis*, *Zygostasis*, *Dicrospirillum*, *Entomospira*, *Cacospira*, *Dicrospira*, *Eisenbergia*, *Zettnowia*, *Pseudostreptus*, *Atremis*, *Lamprella*, *Eucystia*, *Dicrobactrum*, *Acystia*, *Migulanum*, *Rhagadascia*, *Kochella*, *Fischerinum*, *Hemallosis*, *Mogallia*, *Paulosarcina* and *Phacelium*. Note that *Corynobacterium* is spelled with an o instead of an e.

Terms accepted from earlier workers that have not previously been

mentioned are: *Spirobacillus* Metschnikoff (Ann. Inst. Past., *3*, 1889, 62), *Photobacterium* Beijerinck, Maanblad voor Natuurwetenschappen Amsterdam, *16*, 1889, 1 and Arch. Neérl. d. Sci. Exactes, *23*, 1889, 401), and *Sclerothrix* Metschnikoff (Arch. f. Path. Anat. u. Physiol., *113*, 1888, 63–94; not *Sclerothrix* Kuetzing, Species Algarum, 1849, 319).

The above outline was changed in 1925, p. 235 ff. (Bakterien-Cyclogenie, Berlin, 390 pp.) by the addition of one new family, *Chondromycidae*, to include the genus *Newskia*, formerly included in *Sphaerotilidae*, and nine genera not previously given as follows: *Chondromyces*, *Cystodesmia*, *Monocystia*, *Ophiocystia*, *Apelmocoena*, *Polyangium*, *Cystoecemia*, *Myxococcus* and *Dactylocoena*. All except *Chondromyces*, *Polyangium* and *Myxococcus* are taken from Enderlein (Bemerkungen zur Systematik der Chondromyciden, Berlin, 1924, 6 pp.).

The new genus *Löhnisium* is added in the Family *Eisenbergiinae* to include the acetic acid and legume bacteria, and he also proposes the generic term *Macrocystita* (p. 278) for certain bacteria described by Peklo (O mšici krváve (Study of the blood louse). Zemědelského Archivu (Agricultural Archives), *1*, 1916) from aphids. According to Enderlein it is not clear whether this genus should be included in the Family *Bacteriidae* or in *Corynobacteriidae*.

Two genera proposed by others are also accepted. These are *Calymmatobacterium* Aragão and Vianna (Mem. Inst. Oswaldo Cruz, *6*, 1912, 211) placed in the family *Migulanidae*, and *Leuconostoc* Van Tieghem placed in the family *Micrococcidae*.

Later Enderlein (Sitzber. Gesell. Naturf. Freunde Berlin, 1930, 104–105) accepts *Serratia* Bizio in place of *Dicrobactrum* and *Leptotrichia* Trevisan in place of *Syncrotis*. *Streptus* with *Streptus scarlatinae* as type species, is proposed to cover the streptococci not included in *Pseudostreptus*.

The outline suggested by Pringsheim (Lotos, *71*, 1923, 357) is similar to that used by Lehmann and Neumann (Atlas und Grundriss der Bakteriologie, 2 vols., 1896, München). It is a conventional division into spherical, rod-shaped and curved forms so far as the true bacteria are concerned except that the pseudomonads are included in the same family as the vibrios and spirilla. *Rhodobacteriales* is recognized as an order to include the sulfur purple bacteria and the nonsulfur purple bacteria. Few details are given in regard to the other orders. His outline follows:

Schizomycetes
- Order I. ***Eubacteriales***
  - Family 1. ***Coccaceae***
    - Genus a. ***Streptococcus***
    - b. ***Micrococcus***
    - c. ***Sarcina***

Family 2. *Bacteriaceae*
Genus a. *Bacterium*
b. *Bacillus*
Family 3. *Spirillaceae*
Genus a. *Pseudomonas*
b. *Vibrio*
c. *Spirillum*
Order II. *Rhodobacteriales*
Family 1. *Rhodobacterinae*
2. *Thiorhodinae*
Order III. *Myxobacteriales*
Family 1. *Myxobacteriaceae*
Order IV. *Mycobacteriales*
Family 1. *Corynebacteriaceae*
2. *Mycobacteriaceae*
3. *Actinomycetaceae*
(Also possibly the long rod, lactic acid bacteria.)
Order V. *Desmobacteriales*
Family 1. *Chlamydobacteriaceae*
2. *Beggiatoaceae*

The first outline classification drawn up by Janke (Allgemeine Technische Mikrobiologie, I Teil, Dresden, 1924, p. 63) is an adaptation and expansion of that drawn up by Migula (System der Bakterien, 1900). The new genera recognized by Janke are *Planostreptococcus* A. Meyer (Die Zelle der Bakterien, Jena, 1912), *Thioploca* Lauterborn (Ber. dtsch. Bot. Gesell., *25*, 1907, 238), *Thiobacterium* Molisch (Cent. f. Bakt., II Abt., *33*, 1912, 55), *Thiobacillus* Beijerinck (Cent. f. Bakt., II Abt., *11*, 1904, 593), *Thiovibrio* Janke (*loc. cit.*), *Thiospirillum* Winogradsky (Beiträge zu Morphol. u. Physiol. d. Bakterien. Heft I. Schwefelbakterien. Leipzig, 1888), *Thiosphaerella* Nadson (Bull. Jar. bot. Petersburg, *13*, 1913, 106; ref. in Cent. f. Bakt., II Abt., *43*, 1915, 469), *Thiovulum* Hintze (Ber. Dtsch. Bot. Gesell., *31*, 1913, 189), *Spirophyllum* Ellis (Proc. Roy. Soc. Edinburgh, *27*, I, 1907, 21; ref. in Cent. f. Bakt., II Abt., *19*, 1907, 502), *Nodofolium* Ellis (Cent. f. Bakt., II Abt., *26*, 1910, 321), and *Actinococcus* Beijerinck (Fol. Microbiol., *2*, 1914, 185).

Janke's outline classification is given below:

Order I. *Eubacteria*
Family 1. *Coccaceae*
Genus a. *Streptococcus*
b. *Micrococcus*
c. *Sarcina*
d. *Planostreptococcus*
e. *Planococcus*
f. *Planosarcina*
Family 2. *Bacteriaceae*
Genus a. *Bacillus*
b. *Bacterium*

Family 3. *Spirillaceae*
Genus a. *Microspira*
b. *Spirillum*
c. *Spirosoma*
Order II. *Rhodobacteria*
Family 1. *Thiorhodaceae*
Subfamily 1a. *Thiocysteae*
Genus a. *Thiocystis*
b. *Thiocapsa*
c. *Thiosphaera*
d. *Thiosphaerion*
e. *Thiosarcina*
Subfamily 2b. *Lamprocysteae*
Genus a. *Lamprocystis*
Subfamily 3c. *Thiopedieae*
Genus a. *Thiopedia*
b. *Thioderma*
Subfamily 4d. *Amoebobacterieae*
Genus a. *Amoebobacter*
b. *Thiothece*
c. *Thiodictyon*
d. *Thiopolycoccus*
Subfamily 5e. *Chromatieae*
Genus a. *Chromatium*
b. *Rhabdochromatium*
c. *Thiorhodospirillum*
Subfamily 6f. *Rhodocapseae*
Genus a. *Rhodocapsa*
b. *Rhodothece*
Family 2. *Athiorhodaceae*
Subfamily 1a. *Rhodocysteae*
Genus a. *Rhodocystis*
b. *Rhodonostoc*
c. *Rhodococcus*
d. *Rhodobacterium*
e. *Rhodobacillus*
f. *Rhodovibrio*
g. *Rhodospirillum*
Order III. *Thiobacteria*
Family 1. *Beggiatoaceae*
Genus a. *Thiothrix*
b. *Beggiatoa*
c. *Thioploca*
Family 2. *Thiobacteriaceae*
Genus a. *Thiophysa*
b. *Thiobacterium*
c. *Thiobacillus*
d. *Thiovibrio*
e. *Thiospirillum*
f. *Thiosphaerella*
g. *Thiovulum*
h. *Achromatium*

Order IV. *Phycobacteria*
Genus a. *Leptothrix*
b. *Clonothrix*
c. *Cladothrix*
d. *Crenothrix*
e. *Phragmidiothrix*
Appendix Genera *Gallionella, Spirophyllum, Nodofolium*
Order V. *Mycobacteria*
Family 1. *Mycobacteriaceae*
Genus a. *Corynebacterium*
b. *Mycobacterium*
Family 2. *Actinomycetaceae*
Genus a. *Actinomyces*
b. *Actinococcus*
Order VI. *Myxobacteria*
Family 1. *Myxobacteriaceae*
Genus a. *Myxococcus*
b. *Chondromyces*
c. *Polyangium*

Lehmann and Neumann (Bakt. Diag., 2 vols., 7th ed., München, 1926–27; Breed, Eng. trans., New York, 1931) developed their first simple and much used outline classification, drawn up in 1896, in later editions of their Determinative Bacteriology. The 1927 Lehmann and Neumann outline is as follows:

Class I. *Schizomycetes*
Order I. *Schizomycetales*
Family 1. *Coccaceae*
Genus a. *Streptococcus*
b. *Sarcina*
c. *Micrococcus*
Sub-genus a. *Diplococcus*
b. (Gram-positive group)
Family 2. *Bacteriaceae*
Genus a. *Bacterium*
Sub-genus a. *Nitrosomonas*
b. *Nitrobacter*
c. *Rhizobium*
d. *Haemophilus*
e. *Brucella*
f. *Pasteurella*
g. (Glanders and dysentery group)
h. (Photogenic group)
i. (Aerogenes group)
j. *Encapsulatus*
k. (Typhoid group)*
l. *Salmonella*
m. (Coli group)*

* In a footnote under these groups, the authors refer to the names given by Castellani and Chalmers.

n. *Acetobacterium*
o. (Cloacae group)
p. (Red chromogens)
q. (Blue and violet chromogens)
r. *Pseudomonas*
s. *Proteus*
App. *Erysipelothrix*
Genus b. *Fusobacterium*
c. *Plocamobacterium*
Family 3. *Desmobacteriaceae*
Genus a. *Beggiatoa*
b. *Leptothrix*
Sub-genus a. *Leptothrix*
b. *Chlamydothrix*
Genus c. *Crenothrix*
d. *Cladothrix*
e. *Thiothrix*
Family 4. *Spirillaceae*
Genus a. *Vibrio*
b. *Spirillum*
Family 5. *Spirochaetaceae*
Genus a. *Spirochaeta*
Family 6. *Bacillaceae*
Genus a. *Bacillus*
Sub-genus a. (Aerobic group)
b. (Anaerobic group)
Order II. *Actinomycetales*
Family 1. *Proactinomycetaceae*
Genus a. *Corynebacterium*
b. *Mycobacterium*
Family 2. *Actinomycetaceae*
Genus a. *Actinomyces*

The generic term *Bacterium* is retained in this outline to cover those groups of the true bacteria that are Gram-negative, non-spore-forming, motile and non-motile rods. Lehmann and Neumann recognize 20 sub-groups in this genus, many of which correspond with the genera recognized in the MANUAL. In an effort to develop a rational nomenclature the term *Acetobacterium* (occurs first in review by Ludwig, Cent. f. Bakt., II Abt., *4*, 1898, 870) is used in place of *Acetobacter*, *Plocamobacterium* (Loewi, Wien. klin. Wchnschr., *33*, 1920, 730) in place of *Lactobacillus*, and *Fusobacterium* (Knorr, Cent. f. Bakt., I Abt., Orig., *89*, 1922, 4) in place of *Fusiformis* without regard to priority. *Encapsulatus* Castellani and Chalmers (Manual Tropical Med., 3rd ed., 1919, 934) is used in place of *Klebsiella* Trevisan (Atti Accad. Fis.-Med.-Stat. Milano, Ser. 4, *3*, 1885, 107).

Janke (Cent. f. Bakt., II Abt., *66*, 1926, 481) reprints the classification developed in the first edition of the present MANUAL and compares it with that proposed by Orla-Jensen and Enderlein.

The second complete outline drawn up by Janke (Oesterr. Bot. Zeitschr., *78*, 1929, 108) is similar to the classification employed by Lehmann and Neumann (Bakt. Diag., 2 vols., 7th ed., München, 1926–27). He follows Enderlein in placing *Azotobacter* in close association with the spore-forming rods. No new generic terms are suggested. His sub-groups of the genus *Bacterium* are even more closely similar to the genera used in the present edition of the MANUAL than are the sub-groups of Lehmann and Neumann.

Family 1. *Coccaceae*
- Genus a. *Micrococcus*
- b. *Neisseria*
- c. *Streptococcus*
  - Divided into 4 groups.
- d. *Sarcina*
  - Divided into 2 groups.

Family 2. *Bacillaceae*
- Genus a. *Bacillus*
  - Divided into 16 groups.
- b. *Azotobacter*

Family 3. *Bacteriaceae*
- Genus a. *Bacterium*
  - Divided into 27 groups.
- b. *Fusiformis*

Family 4. *Corynobacteriaceae*
- Genus a. *Mycobacterium*
- b. *Corynobacterium*
- c. *Actinomyces*

Family 5. *Spirillaceae*
- Genus a. *Microspira*
  - Divided into 2 groups.
- b. *Spirillum*
  - Divided into 2 groups.

Family 6. *Spirochaetaceae*
- Genus a. *Spirochaeta*
- b. *Borrelia*
- c. *Treponema*
- d. *Cristispira*
- e. *Saprospira*
- f. *Leptospira*

Family 7. *Desmobacteriaceae*
- Genus a. *Beggiatoa*
- b. *Thioploca*
- c. *Thiothrix*
- d. *Leptotrichia*
- e. *Crenothrix*
- f. *Sphaerotilus*
- g. *Clonothrix*
- h. *Leptothrix*
- i. *Phragmidiothrix*

Family 8. *Myxobacteriaceae*
Genus a. *Myxococcus*
b. *Polyangium*
c. *Chondromyces*

Pribram (Jour. Bact., *18*, 1929, 361) has rearranged some groups and combined others (e.g., *Rhizobium*, *Diplococcus*, *Leuconostoc*, *Serratia*, *Flavobacterium*, *Chromobacterium*, *Achromobacter*, *Cellulomonas*) recognized in the first edition of the MANUAL with little change in the nomenclature except among the anaerobic non-spore-forming rods and among the spore-forming rods. Unfortunately, he has sometimes used family and species names as generic names, thus in the latter case introducing adjectives and adjectival terms as substantives. New generic terms suggested are: *Dialisterea*, *Bacteroidea*, *Centrosporus*, *Fusibacillus*, *Pseudobacillus*, *Megatherium*, *Flexus*, *Anthrax*, *Botulinus*, *Chauvoea*, *Botulinea*, *Putrificus*, *Welchia*, *Phleobacterium*, *Distasoa*, *Tissieria*, and *Actinoidomyces*. *Astasia* as it appears in this outline does not appear to be the same as *Astasia* Meyer (Flora, *84*, 1897, 185). *Aerobacillus* is not synonymous with *Aerobacillus* Donker (Inaug. Diss., Delft, 1926). *Sideromonas* is accepted from Cholodny (Ber. Deutsch. Bot. Ges., *40*, 1922, 326).

Pribram's complete outline follows:

Class *Schizomycetes*
Subclass A. *Protozoobacteria*
Order I. *Spirochaetales*
Family 1. *Spirochaetaceae*
Genus a. *Spirochaeta*
b. *Treponema*
c. *Spironema*
Family 2. *Cristispiraceae*
Genus a. *Saprospira*
b. *Cristispira*
c. *Leptospira*
Subclass B. *Eubacteria*
Order I. *Protobacteriales*
Family 1. *Nitrobacteriaceae*
Related to *Pseudomonas*
Tribe A. *Hydrogenomonadae*
Genus a. *Hydrogenomonas*
b. *Methanomonas*
c. *Carboxyodomonas*
Tribe B. *Nitrobactereae*
Genus a. *Nitrosomonas*
b. *Nitrobacter*
Family 2. *Thiobacillaceae*
Tribe A. *Thiobacilleae*
Genus a. *Thiobacillus*

Order II. *Metabacteriales*
Family 1. *Pseudomonadaceae*
Tribe A. *Spirilleae*
Genus a. *Spirillum*
Tribe B. *Vibrioneae*
Genus a. *Vibrio*
Tribe C. *Pseudomonadeae*
Genus a. *Pseudomonas*
b. *Azotobacter*
Connects with *Polyangiaceae* and *Nitrobacteriaceae*
Family 2. *Bacteriaceae*
Tribe A. *Aerobactereae*
Genus a. *Aerobacter*
b. *Escherichia*
c. *Salmonella*
d. *Eberthella*
e. *Proteus*
Tribe B. *Pasteurelleae*
Genus a. *Alcaligenes*
b. *Pasteurella*
Connects with *Pfeifferella*
c. *Hemophilus*
Connects with *Dialister*
Family 3. *Micrococcaceae*
Tribe A. *Streptococceae*
Genus a. *Neisseria*
b. *Streptococcus*
Tribe B. *Micrococceae*
Genus a. *Micrococcus*
b. *Staphylococcus*
c. *Sarcina*
Connects with *Algobacteria*
Subclass C. *Mycobacteria*
Order I. *Bacteriomycetales*
Family 1. *Leptotrichaceae*
Tribe A. *Acetobactereae*
Genus a. *Acetobacter*
Connects with *Salmonella* and *Tissieria*
Tribe B. *Leptotricheae*
Genus a. *Kurthia*
b. *Lactobacillus*
Connects with *Corynebacterium*
c. *Leptotrichia*
Connects with *Erysipelothrix*
Family 2. *Bacteroidaceae*
Tribe A. *Dialistereae*
Genus a. ——— Type species *Dialisterea variegata*
Connects with *Distasoa*
b. ——— Type species *Dialisterea variabilis*
c. *Dialister*

Connects with *Hemophilus*
Tribe B. *Bacteroideae*
Genus a. ——— Type species *Bacteroidea multiformis*
b. *Bacteroides*
Connects with *Tissieria*
c. ——— Type species *Bacteroidea fusiformis*
Order II. *Bacillomycetales*
Family 1. *Bacillaceae*
Sub-family 1a. *Aerobacilloideae*
Tribe A. *Aerobacilleae*
Sub-tribe A1. *Centrosporineae*
Genus a. *Centrosporus*
b. *Fusibacillus*
Sub-tribe A2. *Aerobacillineae*
Genus a. *Aerobacillus*
Tribe B. *Pseudobacilleae*
Genus a. *Pseudobacillus*
Sub-family 1b. *Bacilloideae*
Tribe A. *Bacilleae*
Sub-tribe A1. *Bacillineae*
Genus a. *Bacillus*
b. *Megatherium*
Sub-tribe A2. *Astasineae*
Genus a. *Astasia*
b. *Flexus*
Tribe B. *Anthraceae*
Genus a. *Anthrax*
Family 2. *Clostridiaceae*
Sub-family 2a. *Botulinoideae*
Tribe A. *Botulineae*
Genus a. *Botulinus*
b. *Chauvoea*
c. ——— Type species *Botulinea saccharolytica*
d. ——— Type species *Botulinea butyrica*
Tribe B. *Putrificeae*
Genus a. *Putrificus*
Sub-family 2b. *Clostridioideae*
Tribe A. *Welchieae*
Genus a. *Welchia*
Tribe B. *Clostridieae*
Genus a. *Clostridium*
Order III. *Actinomycetales*
Family 1. *Mycobacteriaceae*
Tribe A. *Actinobacilleae*
Genus a. *Pfeifferella*
Connects with *Pasteurella*
b. *Actinobacillus*
c. *Corynebacterium*
d. *Erysipelothrix*
Connects with *Leptotrichia*

Tribe B. *Mycobactereae*
Genus a. *Phleobacterium*
b. *Mycobacterium*
Tribe C. *Tissierieae*
Genus a. *Distasoa*
b. *Tissieria*
Connects with *Bacteroides*, *Corynebacterium* and *Acetobacter*
Family 2. *Actinomycetaceae*
Tribe A. *Actinoidomycetaceae*
Genus a. *Actinoidomyces*
Tribe B. *Actinomycetaceae*
Genus a. *Actinomyces*
Subclass D. *Algobacteria*
Order I. *Desmobacteriales*
Family 1. *Sphaerotilaceae*
Genus a. *Sphaerotilus*
Order II. *Siderobacteriales*
Family 1. *Chlamydotrichaceae*
Tribe A. *Chlamydotricheae*
Genus a. *Leptothrix*
b. *Crenothrix*
Family 2. *Siderocapsaceae*
Genus a. *Didymohelix*
b. *Siderocapsa*
c. *Sideromonas*
Order III. *Thiobacteriales*
Family 1. *Rhodobacteriaceae*
Sub-family 1a. *Chromatoideae*
Tribe A. *Thiocapseae*
Genus a. *Thiocystis*
b. *Thiosphaera*
c. *Thiosphaerion*
d. *Thiocapsa*
e. *Thiosarcina*
f. *Lamprocystis*
Tribe B. *Thiopedieae*
Genus a. *Lampropedia*
b. *Thioderma*
Tribe C. *Amoebobacteriae*
Genus a. *Amoebobacter*
b. *Thiodictyon*
c. *Thiothece*
d. *Thiopolycoccus*
Tribe D. *Chromatieae*
Genus a. *Chromatium*
b. *Rhabdomonas*
c. *Thiospirillum*
d. *Rhodocapsa*
e. *Rhodothece*

Sub-family 1b. *Rhodobacteroideae*
Tribe A. *Rhodobacteriaceae*
Genus a. *Rhodobacterium*
b. *Rhodobacillus*
c. *Rhodovibrio*
d. *Rhodospirillum*
e. *Rhodosphaera*
Tribe B. *Rhodocysteae*
Genus a. *Rhodocystis*
b. *Rhodonostoc*
Connects with *Leuconostoc*
Family 2. *Beggiatoaceae*
Genus a. *Thiothrix*
b. *Beggiatoa*
c. *Thioploca*
Family 3. *Achromatiaceae*
Genus a. *Achromatium*
b. *Thiophysa*
c. *Thiospira*
d. *Hillhousia*
Order IV. *Myxobacteriales*
Family 1. *Polyangiaceae*
Genus a. *Chondromyces*
b. *Polyangium*
Family 2. *Myxococcaceae*
Genus a. *Myxococcus*

Later Pribram (Klassification der Schizomyceten (Bakterien), Leipzig and Wien, 1933, 143 pp.) developed this classification into a suggestive outline based on his experience in caring for the cultures of the Kral Collection. His most interesting contribution is the separation of the class of *Schizomycetes* into three subclasses which are based on differences in fundamental biological and nutritional relationships. The fourth sub-class of his earlier outline (the *Protozoobacteria* with its single order *Spirochaetales*) is omitted from this outline. The first class, *Algobacteria*, includes the bacteria that are primarily free living in water, usually motile with polar flagellation and live on easily soluble foodstuffs. They are frequently surrounded by insoluble secretions such as capsules, sheaths, etc., and form insoluble products in their protoplasm, such as calcium, sulfur and iron compounds, and pigments. The class *Eubacteria* includes those bacteria whose normal habitat is the animal body or complex waste products of plant or animal origin. Because of adaptation to environment, these organisms are motile or non-motile and can utilize compounds of complex molecular structure. The third sub-class, *Mycobacteria*, is adapted to life in soil, and shows a distinct tendency to differentiation in morphology and spore formation.

Internationally accepted rules of nomenclature are generally followed, and the generic terms proposed in his earlier outline that were not formed

in accordance with recommended practices are discarded. He has revived *Ulvina* Kützing, 1837 (status explained by Buchanan, General Systematic Bacteriology, 1925, p. 518) in place of *Acetobacter* Beijerinck and accepted *Plocamobacterium* (Loewi, Wien. klin. Wchschr., *33*, 1920, 730) in place of *Lactobacillus* Beijerinck, 1901. Among the spore-forming rods, he has accepted *Bactrillum* Fischer and *Welchillus* Heller, 1921. *Malleomyces* Hallier (Bot. Ztg., *24*, 1866, 383) is used for the glanders bacillus. *Anthracillus* is apparently new.

The new outline has the following form:

Class. *Schizomycetes*
- Subclass A. *Algobacteria*
  - Order 1. *Micrococcales*
    - Family 1. *Micrococcaceae*
      - Genus a. *Micrococcus*
      - b. *Rhodococcus*
      - c. *Rhodocapsa*
      - d. *Thiocapsa*
      - e. *Thiosphaera*
      - f. *Thiosphaerion*
      - g. *Thiocystis*
      - h. *Lamprocystis*
      - i. *Sarcina*
      - j. *Thiosarcina*
    - Family 2. *Pediococcaceae*
      - Genus a. *Pediococcus*
      - b. *Lampropedia*
      - c. *Thiothece*
      - d. *Thiopolycoccus*
      - e. *Thioderma*
      - f. *Amoebomonas*
      - g. *Rhodothece*
      - h. *Rhodonostoc*
      - i. *Thiophysa*
  - Order 2. *Pseudomonadales*
    - Family 1. *Pseudomonadaceae*
      - Genus a. *Pseudomonas*
      - b. *Rhodobacillus*
      - c. *Chromatium*
      - d. *Nitrosomonas*
      - e. *Vibrio*
      - f. *Rhodovibrio*
      - g. *Myxococcus*
      - h. *Spirillum*
      - i. *Rhodospirillum*
      - j. *Thiospira*
      - k. *Thiospirillum*
    - Family 2. *Serratiaceae*
      - Genus a. *Serratia*
      - b. *Hillhousia*

Family 3. *Nitrobacteriaceae*
Genus a. *Nitrobacter*
b. *Rhodobacterium*
c. *Rhodocystis*
d. *Didymohelix*
e. *Sideromonas*
f. *Siderocapsa*
g. *Chondromyces*
h. *Polyangium*
i. *Amoebobacter*
j. *Thiodictyon*
Family 4. *Azotobacteriaceae*
Genus a. *Rhizobium*
b. *Azotobacter*
Order 3. *Leptotrichales*
Family 1. *Leptotrichaceae*
Genus a. *Leptothrix*
b. *Sphaerotilus*
c. *Crenothrix*
Family 2. *Clonothrichaceae*
Genus a. *Clonothrix*
Order 4. *Rhabdomonadales*
Family 1. *Rhabdomonadaceae*
Genus a. *Beggiatoa*
b. *Rhabdomonas*
c. *Thioploca*
d. *Thiothrix*
Family 2. *Spirochaetaceae*
Genus a. *Spirochaeta*
b. *Treponema*
c. *Leptospira*
d. *Cristispira*
e. *Saprospira*
Subclass B. *Eubacteria*
Order 1. *Aerobacteriales*
Family 1. *Aerobacteriaceae*
Genus a. *Aerobacter*
b. *Escherichia*
c. *Salmonella*
d. *Eberthella*
e. *Shigella*
Family 2. *Pasteurellaceae*
Genus a. *Pasteurella*
b. *Brucella*
c. *Haemophilus*
d. *Neisseria*
Order 2. *Plocamobacteriales*
Family 1. *Streptococcaceae*
Genus a. *Streptococcus*
Family 2. *Ulvinaceae*
Genus a. *Proteus*
b. *Kurthia*

c. *Ulvina*
d. *Plocamobacterium*
e. *Leptotrichia*
Family 3. *Bacteroidaceae*
Genus a. *Dialister*
b. *Aerobacteroides*
c. *Bacteroides*
d. *Fusobacterium*
Subclass C. *Mycobacteria*
Order 1. *Bacillales*
Family 1. *Bacillaceae*
Genus a. *Bactrillum*
b. *Aerobacillus*
c. *Bacillus*
d. *Anthracillus*
Family 2. *Clostridiaceae*
Genus a. *Clostridium*
b. *Welchillus*
Order 2. *Mycobacteriales*
Family 1. *Mycobacteriaceae*
Genus a. *Malleomyces*
b. *Actinobacillus*
c. *Corynebacterium*
d. *Erysipelothrix*
e. *Mycobacterium*
f. *Distasoa*
g. *Tissieria*
Family 2. *Actinomycetaceae*
Genus a. *Actinomycoides*
b. *Actinomyces*

Janke (Cent. f. Bakt., II Abt., *80*, 1930, 481) reprints the earlier outline prepared by Pribram (1929) and, after commenting on Lehmann and Neumann's (1927) outline, proposes an outline which is slightly modified from his own previous (1929) outline. Two new subgeneric terms are used, *Anaerobacillus* and *Eubacterium*. The sub-genus *Aerobacillus* is apparently not the same as *Aerobacillus* Donker (Inaug. Diss., Delft, 1926), nor as *Aerobacillus* Pribram (Jour. Bact., *18*, 1929, 361).

Family I. *Micrococcaceae*
Genus 1. *Micrococcus*
Divided into 2 sections.
2. *Neisseria*
3. *Streptococcus*
Divided into 4 sections.
4. *Sarcina*
Divided into 2 sections.
Family II. *Bacillaceae*
Genus 1. *Bacillus*
Sub-genus a. *Anaerobacillus* or better *Clostridium*
Divided into 6 sections.

b. *Aerobacillus* or better *Eubacillus*
Divided into 10 sections.
Family III. *Bacteriaceae*
Genus 1. *Bacterium*
Sub-genus a. *Pseudomonas*
Divided into 6 sections.
b. *Eubacterium*
Divided into 11 sections.
c. *Trichobacterium*
Divided into 6 sections.
Genus 2. *Fusiformis*
Family IV. *Corynobacteriaceae*
Genus 1. *Mycobacterium*
2. *Pfeifferella*
3. *Erysipelothrix*
4. *Corynobacterium*
5. *Actinomyces*
Family V. *Spirillaceae*
Genus 1. *Microspira* or *Vibrio*
Sub-genus a. *Microspira*
b. *Spirosoma*
Genus 2. *Spirillum*
Sub-genus a. *Spirella*
b. *Dicrospirillum*
Family VI. *Spirochaetaceae*
Genus 1. *Spirochaeta*
2. *Cacospira*
3. *Entomospira*
4. *Treponema*
5. *Cristispira*
6. *Saprospira*
7. *Leptospira*
Family VII. *Desmobacteriaceae*
As in 1929 outline.
Family VIII. *Myxobacteriaceae*
As in 1929 outline.

Kluyver and Van Niel (Cent. f. Bakt., II Abt., *94*, 1936, 369) have developed an outline classification in which they indicate four lines of development from the simplest form of cell that is existent and conceivable, the sphere. They assign family rank to each of these four groups of bacteria, placing the lophotrichous (and related non-motile) rod-shaped bacteria first (*Pseudomonadaceae*). This is followed by the family of spherical bacteria (*Micrococcaceae*) and the family of permanently non-motile, rod-shaped bacteria (*Mycobacteriaceae*). The final family includes the peritrichous (and related non-motile) rod-shaped bacteria, the *Bacteriaceae*. These are grouped in the tribes of each family in accordance with their fundamental metabolism as photo-autotrophic, photo-heterotrophic, chemo-autotrophic and chemo-heterotrophic. Their outline follows:

Family A. *Pseudomonadaceae*
- I. Tribe *Spirilleae*
  - Genus 1. *Thiospirillum*
  - 2. *Phaeospirillum*
  - 3. *Rhodospirillum*
  - 4. *Sulfospirillum*
  - 5. *Spirillum*
- II. Tribe *Vibrioneae*
  - Genus 1. *Chromatium*
  - 2. *Rhodovibrio*
  - 3. *Didymohelix*
  - 4. *Vibrio*
  - 5. *Desulfovibrio*
- III. Tribe *Pseudomonadeae*
  - Genus 1. *Thiothece*
  - 2. *Phaeomonas*
  - 3. *Rhodomonas*
  - 4. *Sulfomonas*
  - 5. *Sideromonas*
  - 6. *Nitrosomonas*
  - 7. *Nitrobacter*
  - 8. *Acetobacter*
  - 9. *Pseudomonas*
  - 10. *Rhizobium*
  - 11. *Azotobacter*
  - 12. *Listerella*
  - 13. *Aeromonas*
  - 14. *Zymomonas*
  - 15. *Methanobacterium*

Family B. *Micrococcaceae*
- IV. Tribe *Micrococceae*
  - Genus 1. *Chlorobium*
  - 2. *Thiopolycoccus*
  - 3. *Rhodococcus*
  - 4. *Achromatium*
  - 5. *Siderocapsa*
  - 6. *Nitrosococcus*
  - 7 *Neisseria*
  - 8. *Micrococcus*
  - 9. *Veillonella*
  - 10. *Peptococcus*
  - 11. *Methanococcus*
- V. Tribe *Sarcineae*
  - Genus 1. *Thiopedia*
  - 2. *Thiosarcina*
  - 3. *Gaffkya*
  - 4. *Sarcina*
  - 5. *Zymosarcina*
  - 6. *Butyrisarcina*
  - 7. *Methanosarcina*

VI. Tribe *Sporosarcineae*
Genus 1. *Sporosarcina*
VII. Tribe *Streptococceae*
Genus 1. *Peptostreptococcus*
2. *Streptococcus*
3. *Betacoccus*
Family C. *Mycobacteriaceae*
VIII. Tribe *Corynebacterieae*
Genus 1. *Corynebacterium*
2. *Fusiformis*
3. *Propionibacterium*
4. *Streptobacterium*
5. *Betabacterium*
IX. Tribe *Mycobacterieae*
Genus 1. *Mycobacterium*
2. *Thermobacterium*
Family D. *Bacteriaceae*
X. Tribe *Bacterieae*
Genus 1. *Kurthia*
2. *Alcaligenes*
3. *Bacterium*
4. *Aerobacter*
XI. Tribe *Bacilleae*
Genus 1. *Bacillus*
2. *Aerobacillus*
3. *Zymobacillus*
4. *Clostridium*
5. *Peptoclostridium*

Some old names are displaced by new descriptive terms: *Phaeospirillum Sulfospirillum*, *Desulfovibrio*, *Phaeomonas*, *Aeromonas*, *Zymomonas*, *Methanobacterium*, *Methanococcus*, *Methanosarcina*, *Butyrisarcina*, *Peptococcus*, *Peptostreptococcus*, *Zymobacillus*. *Rhodomonas* is not used in the same sense as *Rhodomonas* Orla-Jensen (Cent. f. Bakt., II Abt., *22*, 1909, 331 and 334), the latter being a synonym of *Chromatium* Perty (Zur Kenntniss kleinster Lebensformen, 1852). *Sulfomonas* is indicated as new and as a synonym of *Thiobacillus* Beijerinck (Cent. f. Bakt., II Abt., *11*, 1904, 598) although the same term is used by Orla-Jensen (*loc. cit.*). Three new terms are accepted: *Chlorobium* Nadson (Bull. Jard. Bot. St. Petersburg, *6*, 1906, 184), *Zymosarcina* Smit (Die Gärungssarcinen, Jena, 1930) and *Peptoclostridium* (Donker, Inaug. Diss., Delft, 1926).

Rahn (Cent. f. Bakt., II Abt., *96*, 1937, 273) has reviewed the characters of the species of *Eubacteriales* included in the fourth edition of this MANUAL. He places 146 of the spore-forming species in a Sub-order *A*. *Endosporales* with a single family, and 536 of the species of non-spore-forming rods in a Sub-order *B*. *Asporales* in seven families. Unclassifiable species (total 224) are placed in a temporary eighth family *Bacteriaceae*. His outline follows:

Order *Eubacteriales*
- Suborder A. *Endosporales*
  - Family I. *Endosporaceae*
    - Genus 1. *Bacillus*
    - 2. *Aerobacillus*
    - 3. *Clostridium*
- Suborder B. *Asporales*
  - Family I. *Gramoxidaceae*
    - Genus 1. *Micrococcus* (including *Staphylococcus, Gaffkya, Rhodococcus* and most of the species of *Sarcina*)
    - 2. *Kurthia*
  - Family II. *Gramanoxidaceae*
    - Tribe a. *Streptococceae*
      - Genus 1. *Streptococcus* (including *Diplococcus*)
      - 2. *Leuconostoc*
      - 3. *Peptostreptococcus*
    - Tribe b. *Lactobacilleae*
      - Genus 4. *Lactobacillus* (including part of *Bacteroides*)
      - 5. *Propionibacterium*
    - Tribe c. *Sarcineae*
      - Genus 6. *Zymosarcina*
      - 7. *Butyrisarcina*
      - 8. *Methanosarcina*
  - Family III. *Neissereaceae*
    - Genus 1. *Neisseria*
    - 2. *Veillonella*
  - Family IV. *Protobacteriaceae*
    - Tribe a. *Protobacterieae*
      - Genus 1. *Carboxydomonas*
      - 2. *Methanomonas*
    - Tribe b. *Nitrobacterieae*
      - Genus 1. *Nitrosomonas*
      - 2. *Nitrobacter*
      - 3. *Nitrosococcus*
  - Family V. *Enterobacteriaceae*
    - Genus 1. *Enterobacter* (including *Escherichia, Salmonella, Aerobacter, Klebsiella, Proteus, Erwinia, Eberthella, Shigella,* and parts of *Serratia, Pseudomonas, Flavobacterium* and *Achromobacter*)
  - Family VI. *Pseudomonadaceae*
    - Genus 1. *Pseudomonas* (includes *Phytomonas* and other lophotrichous types only)
    - 2. *Vibrio*
    - 3. *Spirillum*
    - 4. *Acetobacter*
    - 5. *Azotobacter*
    - 6. *Rhizobium*

Family VII. *Parvobacteriaceae*
Genus 1. *Brucella*
2. *Pasteurella*
3. *Hemophilus* (including *Dialister*)
Family VIII. *Bacteriaceae*
Unclassifiable genera including *Alcaligenes* and *Protaminobacter;* some species from each of the following genera, *Achromobacter, Chromobacterium, Cellulomonas, Bacteroides, Flavobacterium, Phytomonas, Pseudomonas, Serratia;* and three species from the Family *Nitrobacteriaceae.*

One of the generic terms used in this outline is new, i.e., *Enterobacter.* Two other generic terms, *Fluorescens* and *Erythrobacterium,* are proposed incidentally (p. 284). The first includes the peritrichous forms included in the MANUAL under *Pseudomonas* and the second includes those red, non-spore-forming rods that are not included in *Serratia.* In another footnote (p. 281) a substitute, *Virgula,* is suggested for *Enterobacter.* Emphasis is placed on sporulation, Gram stain, and oxygen demand as the most important characters aside from cell form and flagellation.

Prévot, as an outgrowth of his studies on anaerobes with Weinberg (Weinberg, Nativelle and Prévot, Les microbes anaérobies, 1937, 1186 pp., Paris), has written a series of papers in which he has developed a classification of anaerobic bacteria (Ann. Sci. Nat., 10 Sér., *15*, 1933, 23–260; Ann. Inst. Past., *60*, 1938, 285–307; *61*, 1938, 72–91; *64*, 1940, 117–125). The conclusions reached in these studies are summarized in his Manual de Classification et de Détermination des Bactéries Anaérobies, Monographie de l'Institut Pasteur, Paris, 1940, 223 pp. He regards the bacteria as comprising a kingdom, *Schizomycetes,* intermediate between the animal and plant kingdoms and notes the presence of strict anaerobes in at least three of the seven orders recognized in the 5th edition of the MANUAL. These orders he regards as classes. The genus *Bacteroides* Castellani and Chalmers (Manual of Trop. Med., 3rd ed., 1919, 959) type species, *Bacteroides fragilis,* is dropped (Ann. Inst. Past., *60*, 1938, 288), and several new terms are proposed for the organisms included by Castellani and Chalmers and later investigators in the genus. Among the new generic names is *Ristella* which is based on *Ristella fragilis,* the species used by Castellani and Chalmers as the type species for *Bacteroides.*

The complete outline classification developed by Prévot in his Monograph (*loc. cit.*, p. 17) is given below:

Kingdom. *Schizomycetes* Nägeli
Class I. *Eubacteriales*
Sub-Class I. Non sporogenous *Eubacteriales*
Order I. *Micrococcales*

Family I. *Neisseriaccae*
Tribe I. *Neissericae*
Genus a. *Neisseria*
Tribe 2. *Veillonelleae*
Genus a. *Veillonella*
Family 2. *Micrococcaceae*
Tribe 1. *Streptococceae*
Genus a. *Diplococcus*
b. *Streptococcus*
Tribe 2. *Staphylococceae*
Genus a. *Gaffkia*
b. *Staphylococcus*
Tribe 3. *Micrococceae*
Genus a. *Sarcina*
b. *Micrococcus*
Order II. *Bacteriales*
Family 1. *Ristellaceae*
Genus a. *Ristella*
b. *Pasteurella*
c. *Dialister*
d. *Zuberella*
e. *Capsularis*
Family 2. *Bacteriaceae*
Genus a. *Eubacterium*
b. *Catenabacterium*
c. *Ramibacterium*
d. *Cillobacterium*
Order III. *Spirillales*
Family 1. *Vibrionaceae*
Genus a. *Vibrio*
Sub-class II. Sporogenous *Eubacteriales*
Order I. *Clostridiales*
Family 1. *Endosporaceae*
Genus a. *Endosporus*
b. *Paraplectrum*
Family 2. *Clostridiaceae*
Genus a. *Inflabilis*
b. *Welchia*
c. *Clostridium*
Order II. *Plectridiales*
Family 1. *Terminosporaceae*
Genus a. *Terminosporus*
b. *Caduceus*
Family 2. *Plectridiaceae*
Genus a. *Plectridium*
b. *Acuformis*
Order III. *Sporovibrionales*
Family 1. *Sporovibrionaceae*
Genus a. *Sporovibrio*

Class II. *Actinomycetales*
- Family 1. *Spherophoraceae*
  - Genus a. *Spherophorus*
  - b. *Spherocillus*
  - c. *Fusiformis*
  - d. *Fusocillus*
  - e. *Leptotrichia*
- Family 2. *Actinomycetaceae*
  - Genus a. *Actinobacterium*
  - b. *Bifidibacterium*
  - c. *Corynebacterium*

Class III. *Spirochetales*
- Family 1. *Spirochaetaceae*
  - Genus a. *Treponema*
  - b. *Borrelia*

In this outline, there are minor modifications in the names and in endings given to the orders and tribes as compared with those given in his preliminary papers. In the Order *Micrococcales*, *Leuconostoc* has been dropped as a genus of the tribe *Streptococceae* and *Rhodococcus* has been dropped as a genus of the Tribe *Staphylococceae*. *Veillonella* proposed by Prévot as a new genus in 1933 (*loc. cit.*, p. 70) is included as a genus in the Family *Neisseriaceae*. The spelling of *Gaffkya* is changed to *Gaffkia*. In the first of Prévot's papers published in 1938 (*loc. cit.*), he proposes the following new genera in the Order *Bacteriales: Ristella*, *Zuberella*, *Capsularis*, *Eubacterium*, *Catenabacterium*, *Ramibacterium* and *Cillobacterium*. In the same paper he also proposes the following new genera in the Order *Actinomycetales: Spherophorus*, *Spherocillus*, *Fusocillus*, *Pseudoleptothrix* (withdrawn in 1940 in favor of *Leptotrichia* Trevisan). He also accepts one genus *Actinobacterium* (Haas, Cent. f. Bakt., I Abt., Orig., *40*, 1906, 180) not previously mentioned in this discussion. With the single change noted (*Pseudoleptothrix* to *Lepototrichia*), the outlines of the genera in the orders *Bacteriales* and *Actinomycetales* remains in the 1940 outline as it was given in 1938.

In the outline given in Prévot's Monograph (*loc. cit.*, p. 17) one change is made in the generic terms recognized in the Order *Clostridiales* from those recognized in his second paper published in 1938. The genus name *Palmula* proposed in 1938, having been found to be invalid because of prior use for a genus of *Protozoa*, is changed to *Acuformis*. Other generic names which appeared for the first time in the 1938 outline are *Endosporus*, *Inflabilis*, *Terminosporus* and *Caduceus*. *Welchia* proposed by Prévot in 1933 (*loc. cit.*, p. 44) was previously proposed by Pribram (Jour. Bact., *18*, 1929, 374) for the same group of anaerobic spore-forming rods. A third order, *Sporovibrionales*, is proposed by Prévot in his Monograph (*loc. cit.*, p. 15) to include the family *Sporovibrionaceae* (Ann. Inst. Past., *64*, 1940,

119). This order and family include a single genus *Sporovibrio* Starkey (Arch. f. Microb., *9*, 1938, 300) syn. *Desulfovibrio* Kluyver and Van Niel (Cent. f. Bakt., II Abt., *94*, 1936, 389). Two genera (*Treponema* and *Borrelia*) of *Spirochaetales* are listed by Prévot in his Monograph (*loc. cit.*, p. 16) as including anaerobic species.

Stanier and Van Niel (Jour. Bact., *42*, 1941, 437–466) have proposed a rearrangement of the classification outline as indicated below:

Kingdom *Monera*
- Division I *Myxophyta* (Blue-green algae)
- Division II *Schizomycetae* (Bacteria)
  - Class I *Eubacteriae*
    - Order I *Rhodobacteriales*
    - Order II *Eubacteriales*
    - Order III *Actinomycetales*
  - Class II *Myxobacteriae*
    - Order I *Myxobacteriales*
  - Class III *Spirochaetae*
    - Order I *Spirochaetales*

Appendix to Division *Schizomycetae*
- Group I Includes two families, *Leptotrichaceae* and *Crenothricaceae*
- Group II *Achromatiaceae*
- Group III *Pasteuriaceae* (Includes three genera, *Pasteuria*, *Hyphomicrobium* and *Blastocaulis*)

The genera *Mycobacterium*, *Corynebacterium*, *Erysipelothrix*, *Leptotrichia*, *Nevskia*, *Gallionella*, *Caulobacter*, *Thiospira*, *Siderocapsa* and *Sideromonas* are placed in *Eubacteriales*. Two genera not previously discussed in this review whose relationships to other bacteria have recently been clarified are *Sporocytophaga* Stanier (Jour. Bact., *40*, 1940, 629) and *Cytophaga* Winogradsky (Ann. Inst. Past., *43*, 1929, 578).

This rearrangement has been carried out by including the organisms placed in the Order *Caulobacteriales* Henrici and Johnson (Jour. Bact., *30*, 1935, 61–93) in the Order *Eubacteriales* (Buchanan, Jour. Bact., *2*, 1917, 162). The genera of the Order *Chlamydobacteriales* Buchanan (*loc. cit.*) are transferred to an appendix or are dropped (*Clonothrix*) as belonging to the blue-green algae. Three of the remaining five orders are raised to the rank of classes, one of which (*Eubacteriae*) includes three orders *Rhodobacteriales* (Pringsheim, Lotos, *71*, 1923, 351), *Eubacteriales* (Buchanan, *loc. cit.*) and *Actinomycetales* (Buchanan, *loc. cit.*). *Rhodobacteriales* includes the sulfur purple, the non-sulfur purple and the green bacteria, the colorless sulfur bacteria (*Beggiatoaceae*) being transferred to the *Myxophyta* with the change of the name of the Order from *Thiobacteriales* Buchanan (*loc. cit.*) to *Rhodobacteriales* Pringsheim (*loc. cit.*).

The outline classification below is proposed by the Editorial Board of the MANUAL for use in the present (6th) edition of the MANUAL. It is based on those developed by Bergey et al. in earlier editions. These, in turn, were based on the outline classifications developed by Buchanan (Jour. Bact., *1*, 1916, 591; *2*, 1917, 155 ff.; *3*, 1918, 27 ff.) and Winslow et al. (Jour. Bact., *5*, 1920, 191).

Phylum *Schizophyta*
- Class I. *Schizophyceae*
- Class II. *Schizomycetes*
  - Order I. *Eubacteriales*
    - Sub-Order I. *Eubacteriineae* (includes *Corynebacteriaceae*)
    - Sub-Order II. *Caulobacteriineae*
    - Sub-Order III. *Rhodobacteriineae*
  - Order II. *Actinomycetales* (includes *Mycobacterium*, *Actinomyces*, and related genera)
  - Order III. *Chlamydobacteriales*
    - Family I. *Leptotrichaceae*
    - Family II. *Crenothrichaceae*
    - Family III. *Beggiatoaceae*
      - Appendix *Achromatiacea*
  - Order IV. *Myxobacteriales*
  - Order V. *Spirochaetales*

Supplement: Groups whose relationships are uncertain.
Group I. Order *Rickettsiales*, Group II. Order *Virales*. Group III. Family *Borrelomycetaceae*.

In this, the arrangement of *Schizomycetes* as a class coordinate with *Schizophyceae*, both belonging to a phylum *Schizophyta* of the plant kingdom, is maintained as before. The number of orders is reduced from seven as given in the fifth edition of the MANUAL to five, through recognition of the fact that the rigid, unicellular, sometimes branching but never truly mycelial nor filamentous organisms belonging to three of the previously recognized orders are presumably more closely related to each other than they are to the organisms in the four remaining orders. The family *Corynebacteriaceae* has been transferred from the order *Actinomycetales* to *Eubacteriales*.

The colorless, filamentous, sulfur bacteria (*Beggiatoaceae*) have been placed in the order *Chlamydobacteriales* with the other filamentous bacteria that are clearly related to the blue-green algae. While this marks the greatest deviation from the outline previously used, and separates these colorless sulfur bacteria from the purple sulfur bacteria placed in *Rhodobacteriineae*, it is in accordance with the arrangement accepted by Lehmann and Neumann (Bakt. Diag., 4 Aufl., *2*, 1907, 598), Pringsheim (Lotos, *71*, 1923, 307) and others. *Rhodobacteriineae* is also limited to the purple and green bacteria as suggested by Pringsheim (*loc. cit.*) and accepted by Kluyver and Van Niel (*loc. cit.*), by Stanier and Van Niel (*loc. cit.*) and others.

The *Rickettsiales* and *Borrelomycetaceae* are placed in a supplement as their relationships are still obscure. Several authors would place them near some of the organisms now placed in *Pasteurella* and *Haemophilus*. The viruses (*Virales*) whose nature and relationships are still more obscure are also placed in a supplemental group.

Although this outline maintains the simplicity that distinguished its predecessors, and provides places for all types of microorganisms thus far described that may properly be grouped under the fission fungi, it should not be regarded in any sense as final. An attempt has been made to express natural relationships, but these are so frequently obscure or unknown that in many places utilitarian considerations have prevailed. In some places, groups of known doubtful significance have been allowed to stand as they are out of a desire not to make unnecessary changes. It has appeared desirable to be conservative in making changes in the outline as used previously.

Addenda: After the above was in page proof, it was discovered that reference to the outline classification of Gieszczykiewicz (Bull. Adad. Polonaise d. Sci. et d. Lettres, Cl. Sci. Math. et Nat., Sér. B., 1939, 27 pp.) had inadvertently been omitted. This outline has some features like the outline that Lehmann and Neumann used in 1927 (see p. 17) and some like the outline used in the 4th ed. of the MANUAL.

The genus *Bacterium* is retained as in the Lehmann and Neumann outline for Gram-negative, non-spore-forming, peritrichous or polar flagellate rods. Twelve sub-genera are recognized and these bear subgeneric scientific names that are much the same as those used for genera in the 4th ed. of the MANUAL. A new subgeneric name *Enterobacterium* (see *Enterobacter* Rahn) is proposed to cover the genera *Escherichia*, *Aerobacter*, *Klebsiella*, *Salmonella*, *Eberthella* and *Shigella*. *Loefflerella* previously used by Gay et al. (Agents of Disease and Heat Resistance, Indianapolis, 1935, 782) is here also used as a subgeneric name for the glanders bacillus; and *Chromobacterium* is used for the organisms more properly placed in *Serratia* Bizio.

Corynebacterium is transferred from the order *Actinomycetales* to *Eubacteriales* and the family *Corynebacteriaceae* is made to include *Lactobacillus*, *Erysipelothrix* and *Fusobacterium*. Among the *Spirochaetales*, the genus name *Spirochaeta* is displaced by a new generic term, *Ehrenbergia*, and is itself used to displace *Borrelia*.

A seventh order *Rickettsiales* is proposed to include two families: *Rickettsiaceae* with one genus *Rickettsia* da Rocha Lima (Berl. klin. Wchnschr., 1916, 567); and *Bartonellaceae* with the genera, *Bartonella* Strong, Tyzzer, Brues, Sellards and Gastiaburú (Jour. Amer. Med. Assoc., *61*, 1913, 1713), and *Grahamella* Brumpt (Bull. Soc. Path. Exot., *4*, 1911, 514).

During 1945, Soriano (Ciencia e Investigación, *1*, 1945, 92–94 and 146–147; Rev. Argentina de Agronomia, *12*, 1945, 120) proposed an arrangement of the Class *Schizomycetes* in which he recognizes a new Order, *Flexibacteriales*, to include the families *Cytophagaceae* and *Beggiatoaceae* and an entirely new Family *Flexibacteriaceae* containing a single genus *Flexibacter*. The latter includes five newly recognized species of flexuous bacteria as follows: *Flexibacter flexilis*, type species, *F. elegans*, *F. giganteus*, *F. albuminosus* and *F. aureus*.

The outline given below shows how this new order and new family are fitted by Soriano into the classification used in the fifth edition of the MANUAL.

Class *Schizomycetes*

Subclass *Eubacteria*. Rigid cells.
- Order I. *Eubacteriales*
- Order II. *Caulobacteriales*
- Order III. *Rhodobacteriales*
- Order IV. *Actinomycetales*
- Order V. *Chlamydobacteriales*

Subclass *Flexibacteria*. Flexuous cells.
- Order VI. *Flexibacteriales*
    - Family I. *Cytophagaceae*
    - Family II. *Beggiatoaceae*
    - Family III. *Flexibacteriaceae*
- Order VII. *Myxobacteriales*
- Order VIII. *Spirochaetales*

Prévot (Ann. Inst. Past. *72*, 1946, 1) has developed his classification of Class *Actinomycetales*, subdividing it into orders and including several genera not recognized in his 1940 outline. This classification is as follows:

Class *Actinomycetales*

Order I. *Actinobacteriales*. New order. Not acid-fast
- Family I. *Spherophoraceae*.
    - Genus I. *Spherophorus*
    - Genus II. *Haverhillia*
    - Genus III. *Spherocillus*
    - Genus IV. *Fusiformis*
    - Genus V. *Fusocillus*
    - Genus VI. *Leptotrichia*
- Family II. *Actinomycetaceae*.
    - Genus I. *Actinomyces*
    - Genus II. *Proactinomyces*
    - Genus III. *Corynebacterium*
    - Genus IV. *Actinobacterium*
    - Genus V. *Bifidibacterium*
    - Genus VI. *Erysipelothrix*

Order II. *Mycobacteriales*. New order. Acid-fast
- Genus I. *Mycobacterium*

This classification differs from that used in this edition of the MANUAL in that it places several genera of Gram-negative organisms in *Actinomycetales*. These are *Spherophorus*, *Haverhillia*, *Spherocillus*, *Fusiformis* and *Fusocillus*, all of which are included here under *Parvobacteriaceae*. *Leptotrichia* which Prévot regards as Gram-negative is generally accepted as being a Gram-positive group. It is discussed in this edition of the MANUAL in connection with the genus *Lactobacillus*.

HOW BACTERIA ARE NAMED AND IDENTIFIED*

Some principles of taxonomy and nomenclature. "Taxonomy is that branch of biology that deals with the orderly arrangement of plants and animals" (Johnson, Taxonomy of the Flowering Plants, New York, 1931, p. 3).

The necessity for applying names to species or kinds of bacteria is self-evident. It is highly desirable that the name applied to an organism by one person should be understood by others. It is further desirable that as far as practicable all individuals use the same name for the same kind of organism. It is helpful, therefore, if there can be an agreement regarding the method of naming organisms, and as to the correct name for each organism. The term *nomenclature* is applied to the naming of plants and animals, and under this term may be included all discussions as to methods of naming and correctness of particular names.

It is not enough that bacteria be named. Some method of classification of the bacteria is essential if the names are to be rendered accessible and available, and identification of unknown forms be made possible. *Taxonomy* is that branch of biology which treats of classification in accordance with a convention or law. It is apparent that taxonomy must be dependent in part for its satisfactory development upon nomenclature. Even though there may not be agreement among bacteriologists as to the exact classification that is to be used, nevertheless it is highly desirable that there be agreement as to some of the fundamental characteristics of satisfactory biological classifications in general.

What kinds of names are used. Two kinds of names are commonly given to the different kinds of plants and animals, the common, provincial, vernacular or casual names on the one hand and the international or scientific names on the other. These should be carefully differentiated, and their respective advantages and disadvantages noted.

It is inevitable, and on the whole probably desirable, that for each kind of familiar animal or plant in each language there will be coined a name. Usually the name for the same organism will be different in each language. For example, we have in English *Oak*, in German *Eiche*, in Latin *Quercus*, etc. For many uncommon kinds, however, there may be no such vernacular names developed. There have been, of course, many casual or vernacular names given to kinds of bacteria. In English we speak of the tubercle bacillus, the typhoid germ, the gonococcus, the Welch bacillus, the golden

* Contributed by Prof. R. E. Buchanan, Iowa State College, Ames, Iowa, January, 1934; revised, March, 1943.

pus coccus, and many others. Similarly, we find in German Typhusbazillen and in French bacille typhique, enterococcus, etc. The use of these common names offers certain advantages. It does away frequently with the necessity of repeating longer and more formal scientific names. Not infrequently scientific names may be adopted into a language, and converted into vernacular names. For example, the English name *aster* and the scientific generic name *Aster* are applied to the same group. This is frequently a convenience, but there are also some difficulties, which will be emphasized below.

In contrast to common, vernacular or casual names, the scientific name for each kind of organism (each plant or animal) is supposed to be the same in all countries and in all languages. When such a scientific name is used, no question should arise in any language as to what organism is intended. The names thus applied are supposed to conform to certain general rules that have been formulated by international agreement. Obviously the use of such names is advantageous whenever one is desirous of accuracy, and of being definitely understood in all languages. It is further evident that in all questions relating to taxonomy and classification it is highly desirable that the scientific names be used.

International rules for nomenclature. In order that there be an international set of scientific names, it is essential that there be an international agreement as to the rules which should govern their creation. Both of the great groups of biologists, the botanists and the zoologists, have met in numerous international congresses in which delegates were accredited by the great botanical and zoological societies, museums, and educational institutions of the world. Codes of nomenclature designed to tell how names shall be manufactured and used, and how to tell which of two or more names that have been used is correct, have been developed by each of these groups. These codes or lists of rules and recommendations are quite similar in essentials for botany and zoology, although they differ in some details.

The question arises: Are either or both of these codes satisfactory or adaptable to the use of bacteriologists. Three views have been expressed by various writers. Some few have suggested that the naming of bacteria cannot well conform to the approved international rules as their classification involves considerations not familiar to botanists and zoologists generally. The second group, also a very small one, has insisted that unicellular forms of life are neither plants or animals, but protista, and that taxonomic rules, etc., should be distinct for this group and coördinate with the corresponding rules for plants and for animals.

The third view, more commonly expressed, is that the bacteria are sufficiently closely related to the plants and animals, so that (in so far as

they apply) the international agreements of the botanists (or zoologists) should be used as a basis for naming them.

International opinion on this topic was finally crystallized by resolutions adopted by the First International Congress of the International Society for Microbiology held in Paris in 1930 and by the Fifth International Botanical Congress held in Cambridge, England in the same year.

The resolutions unanimously adopted by the plenary session of the International Society for Microbiology were in part as follows:

"It is clearly recognized that the living forms with which the microbiologists concern themselves are in part plants, in part animals, and in part primitive. It is further recognized that *in so far as they may be applicable and appropriate* the nomenclatural codes agreed upon by International Congresses of Botany and Zoology should be followed in the naming of micro-organisms. Bearing in mind, however, the peculiarly independent course of development that bacteriology has taken in the past fifty years, and the elaboration of special descriptive criteria which bacteriologists have of necessity developed, it is the opinion of the International Society for Microbiology that the bacteria constitute a group for which special arrangements are necessary. Therefore the International Society for Microbiology has decided to consider the subject of bacterial nomenclature as a part of its permanent program."

The International Society of Microbiologists established a permanent Nomenclature Committee to pass upon suggestions and to make recommendations. This committee is composed of members from all participating nations. Two secretaries were named, one (Dr. St. John-Brooks of the Lister Institute, London, England) to represent primarily medical and veterinary bacteriology, and one (Dr. R. S. Breed, New York State Agricultural Experiment Station, Geneva, New York, U. S. A.) to represent other phases of bacteriology.

The coöperation of the International Botanical Congress was solicited in the naming of this committee. The resolutions were approved by the Section on Bacteriology of the Botanical Congress and the Congress itself incorporated into the Botanical Code certain special provisions relating to the bacteria. It also specifically recognized the International Committee as the body to prepare recommendations relating to bacterial nomenclature.

It is apparent, therefore, that there has been international agreement (in so far as this can be achieved) that bacteriologists should follow the botanical or zoological codes in the naming of bacteria to the extent they are applicable, and that exceptions or new problems should be presented to the International Committee.

These rules are so important in determining the validity of bacterial names that the rules of the Botanical Code are included in somewhat

abridged form in the section that follows this introduction. Any student who has occasion to name a new species or a new genus or determine the validity of a name should familiarize himself with these rules and recommendations.

An effort has been made in the present volume to use nomenclature in conformity with these rules.

Some general principles of nomenclature. Every student of bacteriology should be familiar with certain rules of nomenclature if he is to use names intelligently. If he wishes to correct names improperly used or if he desires to name new species, there are additional rules which he must observe.

1. Each distinct kind of bacterium is called a species.

2. To each distinct species a name is given consisting usually of two Latin words, as *Bacillus subtilis*.

3. The first word is the name of the genus or group to which the organism belongs. It is *always* written with a capital letter. It is a Latin or Greek word, or a new word compounded from Latin or Greek roots, or it may be derived from some other language; but this is important, whatever its origin when used as a generic name it must be regarded and treated as a Latin noun. If it is a word not found in classic Latin, it is regarded as modern Latin. Some generic names in bacteriology which are Latin or formed from Latin roots are *Bacillus* (masculine) a small rod; *Cristispira* (feminine) a crested spiral; *Lactobacillus* (masculine) a milk small rod; *Sarcina* (feminine) a packet or bundle. Many others are words from the Greek or compounded from Greek roots, with the words transliterated into Latin letters and endings in conformity with Latin usage; words of Greek origin are *Micrococcus* (masculine) a small grain (sphere); *Bacterium* (neuter) a small rod; *Clostridium* (neuter) a small spindle; *Corynebacterium* (neuter) clubbed small rod; *Actinomyces* (masculine) ray fungus. Other generic names have been given in honor of persons or places as *Beggiatoa* (feminine), *Borrelia* (feminine), *Eberthella* (feminine), *Pasteurella* (feminine), *Erwinia* (feminine), *Zopfius* (masculine).

4. The second word in the scientific name is a *specific* epithet. It is *not* capitalized except that certain authors capitalize species names derived from proper nouns.

It may be:

(a) An adjective modifying the noun, and indicating by its ending agreement with the generic name in gender, as *Bacterium album* (white *Bacterium*), *Bacillus albus* (white *Bacillus*), *Sarcina alba* (white *Sarcina*), *Eberthella dispar* (the different *Eberthella*), *Bacterium variabile* (the variable *Bacterium*), *Brucella melitensis* (the maltese *Brucella*), *Bacillus teres* (the rounded *Bacillus*), *Bacillus graveolens* (sweet-smelling *Bacillus*).

Typical adjectives

Masculine	Feminine	Neuter
albus	*alba*	*album*
niger	*nigra*	*nigrum*
tener	*tenera*	*tenerum*
acer	*acris*	*acre*
variabilis	*variabilis*	*variabile*
dispar	*dispar*	*dispar*
coccoides	*coccoides*	*coccoides*
aerogenes	*aerogenes*	*aerogenes*

(b) An adjective in the form of the present participle of a verb, as *Clostridium dissolvens* (the dissolving *Clostridium*, in the sense of the *Clostridium* which is able to dissolve), *Bacillus adhaerens* (the adhering *Bacillus*), *Acetobacter ascendens* (the climbing *Acetobacter*), *Bacillus esterificans* (the ester-producing *Bacillus*). The endings for present participles used as adjectives are the same for all genders. The past participle is used occasionally, as in *Pseudomonas aptata* (the adapted *Pseudomonas*), *Spirillum attenuatum* (the attenuated *Spirillum*).

(c) A noun in the genitive (possessive) modifying the generic name. There is no necessary agreement in gender or number. Examples, *Clostridium welchii* (Welch's *Clostridium*), *Salmonella pullorum* (the *Salmonella* of chicks), *Streptococcus lactis* (the *Streptococcus* of milk), *Brucella abortus* (the *Brucella* of abortion), *Clostridium tetani* (the *Clostridium* of tetanus), *Diplococcus pneumoniae* (the *Diplococcus* of pneumonia), *Salmonella anatum* (the *Salmonella* of ducks).

(d) A noun in apposition, that is, an explanatory noun. This does not agree necessarily with the generic name in gender. This method of naming is relatively not common in bacteriology. Examples are *Actinomyces scabies* (the scurf or scab *Actinomyces*), *Bacillus lacticola* (the milk-dweller bacillus), *Bacillus radicicola* (the root-dweller bacillus).

5. The author of the name is often indicated following the name of the species, as *Bacillus subtilis* Cohn. Sometimes a name is indicated also in parenthesis, as *Micrococcus luteus* (Schroeter) Cohn. This means that Schroeter first named the species, giving it the name *luteus*, but placed it in another genus (*Bacteridium*). Cohn placed it in a new genus. It should be noted that the name of a person, following the name of an organism is frequently not the person who first discovered or described it, but the person who first gave it the name used. For example, *Clostridium welchii* (Migula) Holland was first described by Dr. Wm. H. Welch, but not named by him. It was named by Migula in honor of Dr. Welch and later it was placed in the genus *Clostridium* by Holland.

6. Sometimes species of bacteria are subdivided into varieties. These are likewise given Latin designations, and the entire name written as:

Streptococcus lactis var. *maltigenes* (the *Streptococcus* of milk producing malt flavor).

Some principles of taxonomy. It is important further that the student of bacteriology recognize the meaning of certain terms used regularly in classifications.

(1) **Species** (plural **species**). A species of plant (or animal) is assumed above to be one kind of plant. But how much difference must exist between two cultures of bacteria before one is justified in regarding the organisms in them as being of distinct kinds or species? No rule can be laid down. It depends largely upon convenience and a more or less arbitrary decision. As stated by Hitchcock (Descriptive Systematic Botany, New York, 1925, p. 8): "The unit of classification is a coherent group of like individuals, called a species. The term is difficult to define with precision because a species is not a definite entity, but a taxonomic concept." Hucker and Pederson (New York Agric. Exper. Sta. Tech. Bull. 167, 1930, p. 39) state: "The difficulty met with among these lower forms in dividing them into well-defined groups has led many to question whether these small groups or 'species' are natural groups and whether such groups can be considered to be similar to 'species' among higher forms. However this may be, it is necessary to arrange bacteria as well as possible into groups or so-called 'species' for convenience in classification," and again (Hucker, New York Agric. Exper. Sta. Tech. Bull. 100, 1924, 29), "characters applicable to the differentiation of species must evidence a certain amount of constancy when studied over a large series of tests. Furthermore, characters adapted to the differentiation of larger natural groups or genera should, in addition to constancy, show some correlation with other constant characteristics. The presence of this relationship or correlation between characters for the division of genera indicates that the groupings are being made along natural rather than artificial lines."

Type culture. It is quite evident that when a new species of bacterium is described, it must include the particular culture from which the species description was made. This original culture is termed the type culture. We may develop a definition as follows:—A species of bacterium is the type culture or specimen together with all other cultures or specimens regarded by an investigator as sufficiently like the type (or sufficiently closely related to it) to be grouped with it. It is self-evident that different investigators may not draw the same boundaries for a given species. This leads to some practical difficulties, but no better definition has been evolved.

There are certain special cases which require brief discussion.

(a) How should one designate the different stages in an organism that exhibits a growth cycle? There seems to be increasing evidence that certain bacteria show cycles in morphology which parallel to some degree those well

known among the fungi. Such, for example, may well be the rough (R) and smooth (S) types described for many bacteria, possibly the filterable stages noted by many authors, the so-called G types, etc. It is evident that an adequate description of any species of bacterium should include a description of each of these stages in the cyclical development wherever such is proved to exist. In all other cases in botany and in zoology which involve growth stages or cycles one stage has been chosen and designated as the mature or adult or perfect stage. In ferns, for example, names and classifications are based largely upon the sporophytic generation, in insects upon the adult or imago, in the rusts upon the stage in which the teleutospores are produced. There has been no international agreement as to what stage should be thus designated for the bacteria. Beyond doubt, it would be the stage which is most easily cultured and studied in the laboratory, the stage with which we are best acquainted in the laboratory. It might easily happen in bacteria (as it has with fungi) that two different stages of the life cycle of single species have been described and named as separate species. When the mistake has been discovered, the name given to the mature or perfect stage is the one that is accepted. In general the descriptions given in the present volume are those which may be regarded as belonging to the perfect stage. Unfortunately it is not yet possible accurately to group the stages in many of the bacteria that have definite growth cycles.

It is desirable frequently to designate the stage with which one is working. This may be done by some conventional symbol, as S (smooth type), G (filterable stage), etc.

(b) How should one designate variants which differ in some minor respects from the type, but which do not constitute growth stages? For example, the species *Bacillus subtilis* normally produces endospores. Suppose that an asporogenous race is derived from such, agreeing with the parent culture in all respects, but showing no tendency to revert to spore production. What such an organism should be called is a matter of judgment. It might frequently be designated as an asporogenous strain, or more technically if one desires as a variety. It might be termed, for example, *Bacillus subtilis* var. *asporus*. In other cases such expressions as *Diplococcus pneumoniae* Type I, or the Rawlings strain of the typhoid bacillus may be used.

Unfortunately there is no general agreement upon the exact significance which the word "strain" should have in bacteriology. It is recommended that it refer merely to source, e.g. the Rawlings strain of *Eberthella typhosa*, and that it be never used to connote a biological character. This would not prevent such expressions as "a non-motile strain of *Salmonella suipestifer*". but it would make erroneous a statement to the effect that the A

strain of influenza virus differs from the B strain in certain ways. In other words, "strain" is not a synonym of "type" or "variety". We may have as many yellow strains of the typhoid bacillus as we have of cultures of it, from different sources or specimens.

(2) **Genus** (plural **genera**). A genus is a group of related species. In some cases a genus may include only a single species (is said to be *monotypic*) in most cases several to many species are included in a genus. The question asked above may be paraphrased. How close must be the resemblances (how close the relationships) among the species of a group to entitle them to inclusion in the same genus? In other words, how is it possible to delimit accurately the boundaries of a genus? This is a matter on which there is no agreement, and probably can be none. Much of the confusion in modern bacteriological terminology is to be attributed to this fact. Nevertheless, in course of time experience tends to delimit many genera with reasonable accuracy. As stated by Hitchcock (Descriptive Systematic Botany, New York, 1925, p. 9): "Convenience may play a rôle in determining generic lines. Extremely large groups may be broken up on the basis of differences of smaller degree not common to a group of closely allied species, than if the group consisted of a few species. In general, the botanist, in delimiting genera, keeps in mind two important requirements, that of showing natural affinities and that of aiding correct identification." However, a genus may be defined helpfully in another way. One of the species described as belonging to a genus is designated as the *type* species. A genus may be defined then, as including this type species together with such other species as the investigator (or taxonomist) regards as sufficiently closely related. It is apparent that some authors may draw the lines narrowly, others broadly. Some authors, for example, recognize only two genera of rod-shaped bacteria, one for those without endospores (*Bacterium*), and one for those producing endospores (*Bacillus*). These genera thus defined are very large, each containing hundreds, perhaps thousands, of species. Other students break up these large genera into many smaller ones. There is not much point to the question as to which is right and which is wrong. A better question is, which is the more convenient, better represents relationships, better facilitates diagnosis and proves most useful. As organisms become better known, it may be possible through the agency of the International Committee on Nomenclature to reach agreements where lack of agreement leads to serious confusion or misunderstanding.

(3) **Family.** A family in taxonomy is a group of related genera. In general the name of the family is made from the name or former name of one of their genera by affixing the suffix *-aceae* to the root. The word is regarded as plural. Among bacterial families commonly recognized are *Bacillaceae*, *Bacteriaceae*, *Micrococcaceae*, *Spirochaetaceae*, *Actinomycetaceae*,

(4) **Order.** An order is a group of related families. It is named usually (not always) by substituting the suffix *-ales* for *-aceae* in the name of the type family. Among ordinal names that have been used in bacteriology are *Actinomycetales*, *Spirochaetales*, *Eubacteriales*.

(5) **Class.** A class is a group of related orders. In this treatise it is considered that the bacteria constitute a class of the plant kingdom, and this is named *Schizomycetes*.

(6) **Other categories.** Other *categories* or *ranks* of names are used for higher groups. Sometimes families are divided into sub-families, these into tribes, these into subtribes, and these finally into genera.

How to identify an organism by name. One of the main purposes of a manual of determinative bacteriology is to facilitate the finding of the correct scientific name of a bacterium. Such is the purpose of this volume. It is well, however, to note some of the reasons why this result, the identification of an unknown culture, may not eventuate. Among these reasons the following may be listed:

(1) The unknown organism awaiting identification by the investigator may easily be one which has never been named, or perhaps adequately described. For the most part there has been little effort on the part of bacteriologists to describe or name bacteria except as they have been found to have some economic significance or possess some striking or unusual characteristics. It is quite probable that there are many times as many species of bacteria undescribed and named as have been described. Such undescribed species are all about us. It is not surprising, therefore, if one frequently encounters undescribed species. When such unnamed species are encountered, particularly if they are of economic importance or are related to such forms, it is highly desirable that they should be described, named and the results published and made accessible.

(2) The unknown organism may have been described and named in some publication, but the description and name have been over-looked in the preparation of the MANUAL. Perhaps the description has been so inadequate or incomplete that it has not been possible to place it in the classification. It should be noted that the number of species that have been described is so great that no one individual can know them all. Progress in classification comes about largely as the result of the work of specialists in particular groups. For example, Ford made a study of all of the aerobic spore-bearing bacteria which he had secured from various sources. He studied also the descriptions of such bacteria in the literature, and then monographed the group. Similar studies on other groups have resulted in more or less complete monographs. Such, for example, are the monographs on the intestinal group by Welden and Levine, of the acetic bacteria by Hoyer, and Visser 't Hooft, of the cocci by Hucker, of the

pathogenic spore-bearing anaerobes by the English Commission, by Weinberg, and by others, of the red, rod-shaped bacteria by Hefferan and by Breed, of the actinomycetes by Waksman and by Lieske, of the root nodule bacteria of legumes by Fred and his co-workers, etc. Unfortunately most groups of bacteria have not thus been monographed. It is evidently the function of a manual such as this to draw largely upon the work of the monographers, and to supplement their achievements as far as possible by less satisfactory consideration of the unmonographed groups.

It is clear that because an organism cannot be identified from this text is not proof that it has not been described and named. The species most closely related may be determined, then the literature searched carefully for species described still more closely related or perhaps one identical.

(3) It is possible, of course, that an error has been made in the selection of the correct name. It is desirable that users of these keys and descriptions should be familiar with the rules governing the correct choice of names, and make suitable corrections where needed.

Steps in determining the name of an organism. The steps in the identification of an unknown organism are usually the following:

(1) Preparation of an adequate description of the organism.

(2) Knowledge of construction and use of keys.

(3) Determination of order, family and genus by use of key.

Preparation of description of organism. Before attempting to determine the name of an "unknown" organism an adequate description is essential. Just what characteristics must be emphasized depends upon the group in which the organism falls. It is desirable that the knowledge of the characters of the unknown be as complete as possible.

Use and construction of keys. An exceptionally clear and satisfactory discussion of the making and use of keys and synopses is given by Hitchcock (Descriptive Systematic Botany, New York, 1925, p. 104). Anyone planning to monograph a group is advised to read this. He states: "A key is an orderly arrangement of a series of contrasting or directly comparable statements, by which groups of the same category may be distinguished and indicated or identified," and "A key is primarily a mechanical device by which one may arrive at the name of the ultimate member of the group." In general the keys used in this MANUAL are *dichotomous*, that is, the successive divisions are in twos, differentiation being into two contrasted groups.

Determination of order, family and genus by use of keys. The method of doing this is discussed in the introduction beginning on page 1.

RULES OF NOMENCLATURE*

In Paris in 1930, the First International Microbiological Congress voted to follow the rules of nomenclature agreed upon by International Congresses of Botany and Zoology "*in so far as they may be applicable and appropriate.*" The adoption of the date of the publication of Species Plantarum by Linnaeus in 1753 as the point of departure for bacteriological nomenclature was recommended. This recommendation was approved by the plenary session of the Microbiological Congress (Proc. 1er Cong. Internat. Microbiol., Paris, 1930, *2*, 1932, 519) and by the plenary session of the Botanical Congress (Rept. Proc. 5th Internat. Bot. Cong., 1930, Cambridge, 1931, p. 16 and 28).

This Congress also provided for the organization of an International Committee on Bacteriological Nomenclature with two permanent secretaries:

1. To represent primarily medical and veterinary bacteriology,—Dr. R. St. John-Brooks, Lister Institute, London, England.
2. To represent primarily other phases of bacteriology,—Dr. R. S. Breed, Experiment Station, Geneva, New York, U. S. A.

During the years that have elapsed since its appointment, this Committee has organized and has taken various actions in the interest of a more stable nomenclature and classification. Some of these have been completed and accepted by the Second International Congress of Microbiology held in London, 1936. These completed actions are quoted below, and are incorporated into the classification used in the descriptive portion of the MANUAL.

The International Rules of Botanical Nomenclature were originally adopted by the International Botanical Congresses of Vienna (1903) and Brussels (1910). They were modified by the Cambridge Congress (1930) so as to accept the type method, and validate species descriptions of bacteria unaccompanied by a Latin diagnosis. Some further but less important modifications were made at the Amsterdam Congress (1935) (See Sprague, Science, *83*, 1936, 416).

The following are the most important of the rules that are of interest to bacteriologists taken from the latest available edition of the Botanical Code (Gustav Fischer, Jena, 1935). Sections that were newly adopted or amended by the Amsterdam Botanical Congress (1935) are indicated in the text.

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* Contributed by Prof. R. S. Breed, New York State Experiment Station, Geneva, New York, September, 1938; revised, October, 1943.

INTERNATIONAL RULES OF BOTANICAL NOMENCLATURE, 1930–1935

Chapter I. General Considerations and Guiding Principles (Art. 1–9)

Art. 1. Botany cannot make satisfactory progress without a precise system of nomenclature, which is used by the great majority of botanists in all countries.

Art. 2. The precepts on which this precise system of botanical nomenclature is based are divided into *principles*, *rules*, and *recommendations*. The principles (Art. 1–9, 10–14, 15–19) form the basis of the rules and recommendations. The object of the rules (Art. 19–74) is to put the nomenclature of the past into order and to provide for that of the future. They are always retroactive; names or forms of nomenclature contrary to a rule (illegitimate names or forms) cannot be maintained. The recommendations deal with subsidiary points, their object being to bring about greater uniformity and clearness in future nomenclature: names or forms contrary to a recommendation cannot on that account be rejected, but they are not examples to be followed.

Art. 3. The rules of nomenclature should be simple and founded on considerations sufficiently clear and forcible for everyone to comprehend and be disposed to accept.

Art. 4. The essential points in nomenclature are: (1) to aim at fixity of names; (2) to avoid or to reject the use of forms and names which may cause error or ambiguity or throw science into confusion.

Next in importance is the avoidance of all useless creation of names.

Other considerations, such as absolute grammatical correctness, regularity or euphony of names, more or less prevailing custom, regard for persons, etc., notwithstanding their undeniable importance, are relatively accessory.

Art. 5. In the absence of a relevant rule, or where the consequences of rules are doubtful, established custom must be followed.

Art. 7. Scientific names of all groups are usually taken from Latin or Greek. When taken from any language other than Latin, or formed in an arbitrary manner, they are treated as if they were Latin. Latin terminations should be used so far as possible for new names.

Art. 8. Nomenclature deals with: (1) the *terms* which denote the rank of taxonomic groups (Art. 10–14); (2) the *names* which are applied to the individual groups (Art. 15–72).

Art. 9. The rules and recommendations of botanical nomenclature apply to all groups of the plant kingdom, recent and fossil, with certain distinctly specified exceptions.

Chapter II. Categories of Taxonomic Groups, and the Terms Denoting Them (Art. 10–14, Rec. I, II)

Art. 10. Every individual plant belongs to a species (*species*), every species to a genus (*genus*), every genus to a family (*familia*), every family to an order (*orda*) every order to a class (*classis*), every class to a division (*diviso*).

Chapter III. Names of Taxonomic Groups (Art. 15–72, Rec. III–L)

Section 1. General Principles: Priority (Art. 15–17, Rec. III)

Art. 15. The purpose of giving a name to a taxonomic group is not to indicate the characters or the history of the group, but to supply a means of referring to it.

Art. 16. Each group with a given circumscription, position, and rank can bear only one valid name, the earliest that is in accordance with the Rules of Nomenclature.

Section 2. The Type Method (Art. 18, Rec. IV–VII)

Art. 18. The application of names of taxonomic groups is determined by means of *nomenclatural types*. A nomenclatural type is that constituent element of a group to which the name of the group is permanently attached, whether as an accepted name or as a synonym. The name of a group must be changed if the type of that name is excluded (see Art. 66).

Section 3. Limitation of the Principle of Priority: Publication, Starting-points, Conservation of Names (Art. 19–22)

Art. 19. A name of a taxonomic group has no status under the Rules, and has no claim to recognition by botanists, unless it is validly published (see Art. 37).

Art. 20. Legitimate botanical nomenclature begins for the different groups of plants at the following dates:

(*h*) *Myxomycetes*, 1753 (Linnaeus, *Species Plantarum*, ed. 1).*

Art. 21. However, to avoid disadvantageous changes in the nomenclature of genera by the strict application of the Rules of Nomenclature, and especially of the principle of priority in starting from the dates given in Art. 20, the Rules provide a list of names which must be retained as exceptions. These names are by preference those which have come into general use in the fifty years following their publication, or which have been used in monographs and important floristic works up to the year 1890.

Section 4. Nomenclature of the Taxonomic Groups According to Their Categories (Art. 23–35, Rec. VII–XX)

1. *Names of Groups above the Rank of Family.*

Rec. IX. Orders are designated preferably by the name of one of their principal families with the ending *-ales*.

2. *Names of Families and Subfamilies, Tribes, and Sub-tribes.*

Art. 23. Names of families are taken from the name or former name of one of their genera and end in *-aceae.*

Art. 24. Names of subfamilies (*subfamiliae*) are taken from the name of one of the genera in the group, with the ending *-oideae*, similarly for tribes (*tribus*), with the ending *-eae*, and for subtribes (*subtribus*) with the ending *-inae.*

3. *Names of Genera and Subdivisions of Genera.*

Art. 25. Names of genera are substantives (or adjectives used as substantives), in the singular number and written with an initial capital, which may be compared with our family names. These names may be taken from any source whatever, and may even be composed in an absolutely arbitrary manner.

Recommendation X. Botanists who are forming generic names show judgment and taste by attending to the following recommendations:

(a) Not to make names long or difficult to pronounce.
(b) Not to dedicate genera to persons quite unconnected with botany or at least with natural science, nor to persons quite unknown.
(c) Not to take names from barbarous languages, unless those names are frequently cited in books of travel, and have an agreeable form that is readily adaptable to the Latin tongue and to the tongues of civilized countries.

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* See page 48 for action on date for *Schizomycetes.*

(d) To indicate, if possible, by the formation or ending of the name the affinities or analogies of the genus.
(e) To avoid adjectives used as nouns.
(f) Not to give a genus a name whose form is rather that of a subgenus or section (e.g. *Eusideroxylon*, a name given to a genus of *Lauraceae*. This, however, being legitimate, cannot be altered).
(g) Not to make names by combining words from different languages (*nomina hybrida*).

4. *Names of Species (binary names).*

Art. 27. Names of species are binary combinations consisting of the name of the genus followed by a single specific epithet. If an epithet consists of two or more words, these must either be united into one or joined by a hyphen. Symbols forming part of specific epithets proposed by Linnaeus must be transcribed.

The specific epithet, when adjectival in form and not used as a substantive, agrees with the generic names.

Recommendations:

XIII. The specific epithet should, in general, give some indication of the appearance, the characters, the origin, the history or the properties of the species. If taken from the name of a person it usually recalls the name of the one who discovered or described it, or was in some way concerned with it.

XIV. Names of men and women, and also of countries and localities used as specific epithets, may be substantives in the genitive (*Clusii*, *saharae*) or adjectives (*Clusianus*, *dahuricus*). It will be well, in the future, to avoid the use of the genitive and the adjectival form of the same epithet to designate two different species of the same genus: e.g. *Lysimachia Hemsleyana* Maximum. (1891), and *L. Hemsleyi* Franch. (1895).

XV. In forming specific epithets botanists will do well to have regard also to the following recommendations:
(a) To avoid those which are very long and difficult to pronounce.
(b) To avoid those which express a character common to all, or nearly all, the species of a genus.
(c) To avoid using the names of little-known or very restricted localities, unless the species is quite local.
(d) To avoid, in the same genus, epithets which are very much alike, especially those which differ only in their last letters.
(e) Not to adopt unpublished names found in travellers' notes or in herbaria, attributing them to their authors, unless these have approved publication.
(f) Not to name a species after a person who has neither discovered, nor described, nor figured, nor in any way studied it.
(g) To avoid epithets which have been used before in any closely-allied genus.
(h) To avoid specific epithets formed of two or more (hyphened) words.
(i) To avoid epithets which have the same meaning as the generic name (pleonasm).

Section 5. Conditions of Effective Publication (Art. 36)

Art. 36. Publication is effected, under these Rules, either by sale or distribution of printed matter or indelible autographs to the general public, or to specified representative botanical institutions.

No other kind of publication is accepted as effective: communication of new names at a public meeting, or the placing of names in collections or gardens open to the public, does not constitute effective publication.

Section 6. Conditions and Dates of Valid Publication of Names (Art. 37–45, Rec. XXI–XXIX)

Art. 37. A name of a taxonomic group is not validly published unless it is both (1) effectively published (see Art. 36), and (2) accompanied by a description of the group or by a reference to a previously and effectively published description of it.

Art. 38. From January 1, 1935, names of new groups of recent plants, *the Bacteria excepted*, are considered as validly published only when they are accompanied by a Latin diagnosis.

Art. 40. A name of a taxonomic group is not validly published when it is merely cited as a synonym.

Art. 42. A name of a genus is not validly published unless it is accompanied (1) by a description of the genus, or (2) by the citation of a previously and effectively published description of the genus under another name, or (3) by a reference to a previously and effectively published description of the genus as a subgenus, section or other subdivision of a genus.

Art. 43. The name of a monotypic new genus based on a new species is validated (1) by the provision of a combined generic and specific description, (2) by the provision of a plate with analyses showing essential characters; but this applies only to plates and generic names published before January 1, 1908.

Art. 44. The name of a species or of a subdivision of a species is not validly published unless it is accompanied (1) by a description of the group, or (2) by the citation of a previously and effectively published description of the group under another name, or (3) by a plate or figure with analyses showing essential characters; but this applies only to plates or figures published before January 1, 1908.

Art. 45. The date of a name or of an epithet is that of its valid publication (see Art. 19, 36). For purposes of priority, however, only legitimate names and epithets published in legitimate combinations are taken into consideration (see Art. 60). In the absence of proof to the contrary, the date given in the work containing the name or epithet must be regarded as correct.

Botanists will do well in publishing to conform to the following recommendations:

XXI. Not to publish a new name without clearly indicating whether it is the name of a family or a tribe, a genus or a section, a species or a variety; briefly, without expressing an opinion as to the rank of the group to which the name is given.

Not to publish the name of a new group without indicating its type (see Recommendation IV).

XXII. To avoid publishing or mentioning in their publications unpublished names which they do not accept, especially if the persons responsible for these names have not formally authorized their publication (see Recommendation XV (e).

XXVI. To give the etymology of new generic names and also of new epithets when the meaning of these is not obvious.

XXVII. To indicate precisely the date of publication of their works and that of the placing on sale or the distribution of named and numbered plants when these are accompanied by printed diagnoses. In the case of a work appearing in parts, the last published sheet of the volume should indicate the precise dates at which the different fascicles or parts of the volumes were published as well as the number of pages in each.

XXVIII. When works are published in periodicals, to require the publisher to indicate on the separate copies the date (year and month) of publication and also the title of the periodical from which the work is extracted.

XXIX. Separate copies should always bear the pagination of the periodical of which they form a part; if desired they may also bear a special pagination.

Section 7. Citation of Authors' Names for Purposes of Precision (Art. 46–49, Rec. XXX–XXXII)

Art. 46. For the indication of the name (unitary, binary, or ternary) of a group to be accurate and complete, and in order that the date may be readily verified it is necessary to cite the author who first published the name in question.

Art. 47. An alteration of the diagnostic characters or of the circumscription of a group does not warrant the citation of an author other than the one who first published its name.

When the changes have been considerable, an indication of their nature and of the author responsible for the change is added, the words *mutatis charact.*, or *pro parte*, or *excl. gen.*, *excl. sp.*, *excl. var.*, or some other abridged indication being employed.

Art. 48. When a name of a taxonomic group has been proposed but not published by one author, and is subsequently validly published and ascribed to him (or her) by another author who supplied the description, the name of the latter author must be appended to the citation with the connecting word "*ex*."

If it is desirable or necessary to abbreviate such a citation, the name of the publishing author, being the more important, must be retained.

When a name and description by one author are published by another author, the word *apud* is used to connect the names of the two authors, except where the name of the second author forms part of the title of a book or periodical in which case the connecting word *in* is used instead.

Art. 49. When a genus or a group of lower rank is altered in rank but retains its name or epithet, the original author must be cited in parenthesis, followed by the name of the author who effected the alteration. The same holds when a subdivision of a genus, a species, or a group of lower rank is transferred to another genus or species with or without alteration of rank.

Section 8. Retention of Names or Epithets of Groups which are Remodelled or Divided (Art. 50–52)

Art. 50. An alteration of the diagnostic characters, or of the circumscription of a group, does not warrant a change in its name, except in so far as this may be necessitated (1) by transference of the group (Art. 53–55), or (2) by its union with another group of the same rank (Art. 56–57), or (3) by a change of its rank (Art. 58).

Art. 51. When a genus is divided into two or more genera, the generic name must be retained for one of them, or (if it has not been retained) must be re-established. When a particular species was originally designated as the type, the generic name must be retained for the genus including that species. When no type was designated, a type must be chosen according to the regulations which will be given (Appendix I).*

Art. 52. When a species is divided into two or more species, the specific epithet must be retained for one of them, or (if it has not been retained) must be re-established. When a particular specimen was originally designated as the type, the specific epithet must be retained for the species including that specimen. When no type was designated, a type must be chosen according to the regulations to be given (Appendix I).

* **Appendix I has not been published as yet. See Type Basis Code, p. 61.**

Section 9. Retention of Names or Epithets of Groups Below the Rank of Genus on Transference to Another Genus or Species (Art. 53–55)

Art. 53. When a subdivision of a genus is transferred to another genus (or placed under another generic name for the same genus) without change of rank, its subdivisional name must be retained, or (if it has not been retained) must be re-established unless one of the following obstacles exists: (1) that the resulting association of names has been previously published validly for a different subdivision, or (2) that there is available an earlier validly published sub-divisional name of the same rank.

Art. 54. When a species is transferred to another genus (or placed under another generic name for the same genus), without change of rank, the specific epithet must be retained or (if it has not been retained) must be re-established, unless one of the following obstacles exists: (1) that the resulting binary name has been previously and validly published for a different species, (2) that there is available an earlier validly published specific epithet.

"When, on transference to another genus, the specific epithet has been applied erroneously in its new position to a different plant, the new combination must be retained for the plant on which the epithet was originally based, and must be attributed to the author who first published it." (Accepted in this revised form at the Amsterdam Botanical Congress, 1935.)

Art. 55. When a variety or other subdivision of a species is transferred, without change of rank, to another genus or species (or placed under another generic or specific name for the same genus or species), the original subdivisional epithet must be retained or (if it has not been retained) must be re-established, unless one of the following obstacles exists: (1) that the resulting ternary combination has been previously and validly published for a subdivision based on a different type, even if that subdivision is of a different rank; (2) that there is an earlier validly published subdivisional epithet available.

When the epithet of a subdivision of a species, on transference to another species, has been applied erroneously in its new position to a different plant, the epithet must be retained for the plant on which the group was originally based.

Example: The variety *micranthum* Gren. & Godf. (*Fl. France*, i, 171: 1847) of *Helianthemum italicum* Pers., when transferred as a variety to *H. penicillatum* Thib., retains its varietal epithet, becoming *H. penicillatum* var. *micranthum* (Gren. & Godr.) Grosser (in Engl. *Pflanzenreich*, Heft 14, 115: 1903).

Section 10. Choice of Names when Two Groups of the Same Rank are United, or in Fungi with a Pleomorphic Life-cycle (Art. 56, 57, Rec. XXXIII–XXXV)

Art. 56. When two or more groups of the same rank are united, the oldest legitimate name or (in species and their subdivisions) the oldest legitimate epithet is retained. If the names or epithets are of the same date, the author who unites the groups has the right of choosing one of them. The author who first adopts one of them, definitely treating another as a synonym or referring it to a subordinate group, must be followed.

Art. 57. Among Fungi with a pleomorphic life-cycle the different successive states of the same species (*anamorphoses, status*) can bear only one generic and specific name (binary), that is the earliest which has been given, starting from Fries, *Systema*, or Fries, *Synopsis*, to the state containing the form which it has been agreed to call the perfect form, provided that the name is otherwise in conformity with the Rules. The perfect state is that which ends in the ascus stage in the *Ascomycetes*,

in the basidium, in the *Basidiomycetes*, in the teleutospore or its equivalent in the *Uredinales*, and in the spore in the *Ustilaginales*.

Generic and specific names given to other states have only a temporary value. They cannot replace a generic name already existing and applying to one or more species, any one of which contains the "perfect" form.

The nomenclature of Fungi which have not a pleomorphic life-cycle follows the ordinary rules.

Section 11. Choice of Names when the Rank of a Group is Changed

Art. 58. When a tribe becomes a family, when a subgenus or section becomes a genus, when a subdivision of a species becomes a species, or when the reverse of these changes takes place, and in general when a group changes its rank, the earliest legitimate epithet given to the group in its new rank is valid, unless that name or the resulting association or combination is a later homonym (see Art. 60, 61).

Section 12. Rejection of Names (Art. 59–69, Rec. XXXVII)

Art. 59. A name or epithet must not be rejected, changed, or modified merely because it is badly chosen, or disagreeable, or because another is preferable or better known (see also Art. 69).

Art. 60. A name must be rejected if it is illegitimate (see Art. 2). The publication of an epithet in an illegitimate combination must not be taken into consideration for purposes of priority, "except as indicated in Art. 61." (Added at the Amsterdam Botanical Congress, 1935.)

A name is illegitimate in the following cases:

(1) If it was superfluous when published, i.e., if there was a valid name (see Art. 16) for the group to which it was applied, with its particular circumscription, position and rank.

(2) If it is a binary or ternary name published in contravention of Art. 16, 50, 52, or 54, i.e., if its author did not adopt the earliest legitimate epithet available for the group with its particular circumscription, position, and rank.

(3) If it is a later homonym (see Art. 61) (except as regards Art. 54 and 55).

(4) If it is a generic name which must be rejected under Art. 67.

(5) If its specific epithet must be rejected under Art. 68.

Art. 61. A name of a taxonomic group is illegitimate and must be rejected if it is a later homonym, that is, if it duplicates a name previously and validly published for a group of the same rank based on a different type. Even if the earlier homonym is illegitimate, or is generally treated as a synonym on taxonomic grounds, the later homonym must be rejected. "When an author simultaneously publishes the same new name for more than one group, the first author who adopts one of them, or substitutes another name for one of them, must be followed." (Added at the Amsterdam Botanical Congress, 1935.)

Art. 62. A name of a taxonomic group must be rejected if, owing to its use with different meanings, it becomes a permanent source of confusion or error. A list of names to be abandoned for this reason (*Nomina ambigua*) will form Appendix IV.*

Art. 63. A name of a taxonomic group must be rejected when its application is uncertain (*Nomen dubium*): e.g., *Ervum soloniense* L. (*Cent.* II. Pl. 28: 1756) is a name the application of which is uncertain; it must, therefore, be rejected (see Schinz and Thell in *Vierteljahrsschr. Nat. Ges. Zürich*, viii, 71: 1913).

* Appendix IV has not been published as yet.

Art. 64. A name of a taxonomic group must be rejected if the characters of that group were derived from two or more entirely discordant elements, especially if those elements were erroneously supposed to form part of the same individual.

A list of names to be abandoned for this reason (*Nomina confusa*) will form Appendix VI.*

Art. 65. A name or epithet of a taxonomic group must be rejected when it is based on a monstrosity.

Art. 66. The name of an order, suborder, family or subfamily, tribe or subtribe must be changed when it is taken from the name of a genus which is known not to belong to the group in question—e.g. if the genus *Portulaca* were excluded from the family now known as *Portulacaceae*, the residual group could no longer bear the name *Portulacaceae*, and would have to be renamed.

Art. 67. Names of genera are illegitimate in the following *special* cases and must be rejected:

(1) When they are merely words not intended as names: e.g. *Anonymous* Walt. (Fl. *Carol.* 2, 4, 9, etc.: 1788) must be rejected as being a word applied to 28 different genera by Walter to indicate that they were without names.

(2) When they coincide with a technical term currently used in morphology unless they were accompanied, when originally published, by specific names in accordance with the binary method of Linnaeus. On and after Jan. 1, 1912, all new generic names coinciding with such technical terms are unconditionally rejected.

(3) When they are unitary designations of species: e.g. Ehrhart (*Phytophylacium:* 1780; and *Beitr.* iv, 145–150: 1798) proposed unitary names for various species known at that time under binary names: e.g. *Phaeocephalum* for *Schoenus fuscus*, and *Leptostachys* for *Carex leptostachys*. These names, which resemble generic names, should not be confused with them, and must be rejected, unless they have been published as generic names by a subsequent author.

(4) When they consist of two words, unless these words were from the first combined into one, or joined by a hyphen.

Art. 68. Specific epithets are illegitimate in the following cases and must be rejected:

(1) When they are merely words not intended as names.

(2) When they are merely ordinal adjectives being used for enumeration.

(3) When they exactly repeat the generic name with or without the addition of a transcribed symbol.

(4) When they were published in works in which the Linnean system of binary nomenclature for species was not consistently employed.

Art. 69. In cases foreseen in Art. 60–68 the name or epithet to be rejected is replaced by the oldest legitimate name, or (in a combination) by the oldest legitimate epithet. If none exists, a new name or epithet must be chosen. Where a new epithet is required, an author may, if he wishes, adopt an epithet previously given to the group in an illegitimate combination, if there is no obstacle to its employment in the new position or sense.

Section 13. Orthography of Names (Art. 70–71, Rec. XXXVIII–XLIV)

Art. 70. The original spelling of a name or epithet must be retained, except in the case of a typographic error, or of a clearly unintentional orthographic error. When the difference between two generic names lies in the termination, these names must

* Appendix VI has not been published as yet.

be regarded as distinct, even though differing by one letter only. This does not apply to mere orthographic variants of the same name.

Note 1. The words "original spelling" in this Article mean the spelling employed when the name was validly published.

2. The use of a wrong connecting vowel or vowels (or the omission of a connecting vowel in a specific epithet, or in that of a subdivision of a species) is treated as an unintentional orthographic error which may be corrected (see Rec. XLIV). "The liberty of correcting a name must be used with reserve, especially if the change affects the first syllable, and above all the first letter of the name." (Added at the Amsterdam Botanical Congress, 1935.)

3. In deciding whether two or more slightly different names should be treated as distinct or as orthographical variants, the essential consideration is whether they may be confused with one another or not: if there is serious risk of confusion, they should be treated as orthographic variants. Doubtful cases should be referred to the Executive Committee.

4. Specific and other epithets of Greek origin differing merely by having Greek and Latin terminations respectively are orthographic variants. Epithets bearing the same meaning and differing only slightly in form are (considered as) orthographic variants. The genitive and adjectival forms of a personal name are, however, treated as different epithets (e.g. *Lysimachia Hemsleyana* and *L. Hemsleyi*).

Recommendations:

XXXVIII. When a new name is derived from a Greek word containing the *spiritus asper* (rough breathing), this should be transcribed as the letter h.

XXXIX. When a new name for a genus, subgenus or section is taken from the name of a person, it should be formed in the following manner:—

(a) When the name of the person ends in a vowel the letter *a* is added (thus *Bouteloua* after Boutelou; *Ottoa* after Otto; *Sloanea* after Sloane), except when the name already ends in *a*, when *ea* is added (e.g. *Collaea* after Colla).

(b) When the name of the person ends in a consonant, the letters *ia* are added (e.g. *Magnusia* after Magnus, *Ramondia* after Ramond), except when the name ends in *er*, when *a* is added (e.g. *Kernera* after Kerner).

(c) The syllables which are not modified by these endings, retain their original spelling, even with the consonants *k* and *w* or with groupings of vowels which were not used in classical Latin. Letters foreign to botanical Latin should be transcribed, and diacritic signs suppressed. The Germanic *ä, ö, ü* become *ae, oe, ue*; the French *é, è, ê* become generally *e*. In works in which diphthongs are not represented by special type, the diaeresis sign should be used where required, e.g., *Cephaëlis*, not *Cephaelis*.

(d) Names may be accompanied by a prefix or a suffix, or modified by anagram or abbreviation. In these cases they count as different words from the original name.

Examples: *Durvillea* and *Urvillea; Lapeyrousea* and *Peyrousea; Englera, Englerastrum* and *Englerella; Bouchea* and *Ubochea; Gerardia* and *Graderia.*

XL. When a new specific or other epithet is taken from the name of a man, it should be formed in the following manner:—

(a) When the name of the person ends in a vowel, the letter *i* is added (thus *Glazioui* from Glaziou, *Bureaui* from Bureau), except when the name ends in *a*, when *e* is added (thus *balansae* from Balansa).

(b) When the name ends in a consonant, the letters *ii* are added (thus *Magnusii* from Magnus, *Ramondii* from Ramond), except when the name ends in *-er* when *i* is added (thus *Kerneri* from Kerner).

(c) The syllables which are not modified by these endings retain their original spelling, even with the consonants *k* or *w* or with groupings of vowels which were not used in classical Latin. Letters foreign to botanical Latin should be transcribed and diacritic signs suppressed. The Germanic *ä*, *ö*, *ü* become *ae*, *oe*, *ou*, the French *é*, *è*, *ê* become generally *e*. The diaeresis sign should be used where required.

(d) When epithets taken from the name of a person have an adjectival form they are formed in a similar way (e.g. *Geranium Robertianum*, *Verbena Hasslerana*).

XLI. The same provisions apply to epithets formed from the names of women. When these have a substantival form they are given a feminine termination (e.g. *Cypripedium Hookerae*, *Rosa Beatricis*, *Scabiosa Olgae*, *Omphalodes luciliae*).

XLII. The specific (or other) epithets should be written in conformity with the original spelling of the words from which they are derived and in accordance with the rules of Latin and latinization.

Examples: *silvestris* (not *sylvestris*) *sinensis* (not *chinensis*).

XLIII. Specific (or other) epithets should be written with a small initial letter, except those which are derived from names of persons (substantives or adjectives), or are taken from generic "or vernacular" names (substantives or adjectives). (Emended Amsterdam Botanical Congress, 1935. See page 61 for actions taken by Second International Microbiological Congress, London, 1936 governing Bacteriological Nomenclature.)

XLIV. In the formation of specific (or other) epithets composed of two or several roots taken from Latin or Greek, the vowel placed between the two roots becomes a connecting vowel, in Latin *i*, in Greek *o*; thus *menthifolia*, *salvifolia*, not *menthaefolia*, *salviafolia*. When the second root begins with a vowel and euphony requires, the connecting vowel should be eliminated (e.g. *lepidantha*). The connecting vowels *ae* should be retained only where this is required for etymological reasons (e.g. *caricaeformis* from *Carica*, in order to avoid confusion with *cariciformis* from *Carex*). In certain compounds of Greek words no connecting vowel is required, e.g. *brachycarpus* and *glycylphyllus*.

Section 14. Gender of Generic Names

Art. 72. The gender of generic names is governed by the following regulations:—

(1) "A Greek or a Latin word adopted as a generic name retains its classical gender. In cases where the classical gender varies, the author has the right of choice between the alternative genders. In doubtful cases, general usage should be followed." "The following names, however, whose classical gender is masculine, are treated as feminine in accordance with historic usage: *Adonis*, *Orchis*, *Stachys*, *Diospyros*, *Strychnos*. *Hemerocallis* (m. in Sp. Pl.: Lat. and Gr. *hemercalles* n.) is also treated as feminine to bring it into conformity with all other generic names ending in *is*." (Emended Amsterdam Botanical Congress, 1935.) See Van Eseltine, Jour. Bact., *26*, 1933, 569, for discussion of the gender of generic names used for bacteria.

(2) Generic names which are modern compounds formed from two or more Greek or Latin words take the gender from the last. If the ending is altered, however, the gender will follow it.

(3) Arbitrarily formed generic names or vernacular names used as generic names take the gender assigned to them by their authors. Where the original

author has failed to indicate the gender, the next subsequent author has the right of choice.

Section 15. Various Recommendations (Rec. XLV–L)

XLV. When writing in modern languages botanists should use Latin scientific names or those immediately derived from them, in preference to names of another kind or origin (popular names). They should avoid the use of the latter unless these are very clear and in common use.

XLVII. Only the metric system should be used in botany for reckoning weights and measures. The foot, inch, line, pound, ounce, etc., should be rigorously excluded from scientific language.

Altitude, depth, rapidity, etc., should be measured in meters. Fathoms, knots, miles, etc., are terms which should disappear from scientific language.

XLVIII. Very minute dimensions should be reckoned in μ (micromillimeters, microns, or thousandths of a millimeter) and not in fractions of millimeters or of lines, etc.: fractions encumbered with ciphers and commas easily give rise to mistakes.

XLIX. Authors should indicate clearly and precisely the scale of the figures which they publish.

L. Temperatures should be expressed in degrees of the centigrade thermometer of Celsius.

Chapter IV. Interpretation and Modification of the Rules (Art. 73, 74)

Art. 73. A small permanent International Executive Committee is established with functions including the following:

(1) Interpreting the Rules in doubtful cases, and issuing considered "Opinions" on the basis of the evidence submitted.

(2) Considering *Nomina conservanda*, *Nomina ambigua*, *Nomina dubia* and *Nomina confusa*, and making recommendations thereon to the next International Botanical Congress.

(3) Considering all proposals for the modification of the Rules and reporting thereon to the next Congress.

(4) Reporting on the effects of modifications of the Rules accepted at the preceding Congress.

Art. 74. These Rules can be modified only by competent persons at an International Botanical Congress convened for the express purpose. Modifications accepted at one Congress remain on trial until the next Congress, at which they will receive sanction unless undesirable consequences, reported to the Executive Committee, show need for further amendment or rejection.

Eight appendices have been or are to be prepared for this Code as follows: (1) †Regulations for determining types, (2) †Nomina conservanda familiarum, (3) *Nomina generica conservanda, (4) †Nomina ambigua, (5) †Nomina dubia, (6) †Nomina confusa, (7) *Representative botanical institutions recognized under Art. 34, (8) †Nomenclature of garden plants.

Unfortunately the first appendix which is of greatest interest to bacteriologists has not been prepared. As many bacteriologists, especially those in other countries, have not caught the significance of the type species

* These appendixes have been prepared.

† These appendixes have not been published as yet.

concept as a means of defining bacterial genera, the reader is referred to the writings of Hitchcock (Amer. Jour. Bot., *8*, 1921, 251; Descriptive Systematic Botany, New York, 1925) for an excellent exposition of the value of this idea to systematists.

Hitchcock (1921, p. 252) explains this concept briefly as follows: "The old concept was that a genus was a group of species having a given combination of characters; a species, similarly, a group of specimens. The new type concept is that, from the nomenclatural standpoint, a genus is a group of species allied to the type species; a species, a group of individuals similar to the type specimen."

Rules for determining types taken from the Type Basis Code of Nomenclature (Science, *49*, 1919, 333; *53*, 1921, 312) drawn up by a Committee of which Hitchcock was Chairman are quoted as these are the most authoritative rules thus far available.

Type Basis Code of Nomenclature (Hitchcock et al.)

Article 4. The nomenclatural type species of a genus is the species or one of the species included when the genus was originally published.

If a genus included but one species when originally published, this species is the type.

When more than one species is included in the original publication of the genus, the type is determined by the following rules:

(a) When, in the original publication of a genus, one of the species is definitely designated as type, this species shall be accepted as the type regardless of other considerations.

If *typicus* or *typus* is used as a new specific name for one of the species, this species shall be accepted as the type as if it were definitely designated.

(b) The publication of a new generic name as an avowed substitute for an earlier one does not change the type of the genus.

(c) If a genus, without an originally designated type, contains among its original species one with the generic name used as a specific name, either as a valid name or synonym, that species is to be accepted as the type.

(d) If a genus, when originally published, includes more than one species, and no species is definitely designated as type, nor indicated according to (c), the choice of the type should accord with the following principles:

1. Species inquirendae or species doubtfully referred to the genus, or mentioned as in any way exceptional are to be excluded from consideration in selecting the type.
2. Genera of the first edition of Linnaeus's "Species Plantarum" (1753) are usually typified through the citations given in the fifth edition of his "Genera Plantarum" (1754) except when inconsistent with the preceding articles.
3. Species which definitely disagree with the generic description (provided others agree), or which possess characters stated in the generic description as rare or unusual, are to be excluded from consideration in selecting the type.

RECOMMENDATIONS

Article 5. In the future it is recommended that authors of generic names definitely designate type species; and that in the selection of types of genera previously published, but of which the type would not be indicated by the preceding rules, the following points be taken into consideration:

(a) The type species should usually be the species or one of the species which the author had chiefly in mind. This is often indicated by

1. A closer agreement with the generic description.
2. Certain species being figured (in the same work).
3. The specific name, such as *vulgaris*, *communis*, *medicinalis* or *officinalis*.

(b) The type species should usually be the one best known to the author. It may be assumed that an indigenous species (from the standpoint of the author), or an economic species, or one grown in a botanical garden and examined by the author, would usually represent an author's idea of a genus.

(c) In Linnaean genera the type should usually be chosen from those species included in the first technical use of the genus in pre-Linnaean literature.

(d) The types of genera adopted through citations of non-binomial literature (with or without change of name) should usually be selected from those of the original species which received names in the first binomial publication.

(e) The preceding conditions having been met, preference should be shown for a species which will retain the generic name in its most widely used sense, or for one which belongs to a division of the genus containing a larger number of species, or, especially in Linnaean genera, for the historically oldest species.

(f) Among species equally eligible, the preference should be given to the first known to have been designated as the type.

(g) If it is impossible to select a type under the conditions mentioned above, the first of equally eligible species should be chosen.

While the rules and recommendations of the above botanical codes are applicable in general to bacteria and related microorganisms, the fact that these are not infallible is evident because the rules developed independently by zoologists (see Proc. Biol. Soc. Washington, *39*, 1926, 75, for the latest Code of Zoological Nomenclature) frequently follow a quite different course. In some cases at least the zoological rules will appeal to microbiologists as more likely to produce uniformity of usage than the botanical rules.

For example, microbiologists assembled at the Second International Microbiological Congress in London, 1936 accepted (Jour. Bact., *33*, 1937, 445) Art. 13 of the International Rules of Zoological Nomenclature as preferable to Rec. 43 of the Botanical Rules to govern bacteriological practice. This reads as follows: "While specific substantive names derived from names of persons may be written with a capital initial letter, all other specific names are to be written with a small initial letter. Some examples taken from bacteriological literature are: *Salmonella Schottmuelleri* or *Salmonella schottmuelleri*, *Bacillus Welchii* or *Bacillus welchii*, *Acetobacter Pasteurianum* or *Acetobacter pasteurianum*, *Corynebacterium ovis*, *Nitrosomonas javanensis*, *Rhizobium japonicum*."

In the MANUAL all species names are written with a small letter. It is felt that the value of a name as a name is lessened if capitals or other marks are used to indicate etymology. The derivation of generic and specific names is given separately in the descriptive material.

Likewise for obvious reasons, microbiologists refused (Jour. Bact., *33*, 1937, 445) to follow the botanical and zoological practice which permits the use of duplicate generic names, one for an animal and the other for a plant group; and accepted the following rules to govern their practice.

"a. Generic homonyms are not permitted in the group *Protista*.
b. It is advisable to avoid homonyms amongst *Protista* on the one hand, a plant or animal on the other."

The following actions of the International Committee on Bacteriological Nomenclature (Cent. f. Bact., II Abt., *92*, 1935, 481) were confirmed (Jour. Bact., *33*, 1937, 445).

Bacillus Cohn 1872 was accepted as a *genus conservandum* with *Bacillus subtilis* Cohn *emend.* Prazmowski 1880 as type species. It was agreed that *Bacillus* should be defined so as to exclude bacterial species which do not form endospores; and that the so-called Marburg strain found in type culture collections should be accepted as the type or standard strain.

At the Third International Congress of Microbiology held in New York City in September, 1939, a series of recommendations of the Permanent International Committees on Bacteriological Nomenclature were accepted at the plenary session of the Congress. The third and fourth recommendations were:

3. That the Nomenclature Committee, as at present constituted, shall continue to function under the auspices of the International Association of Microbiologists as it did under the International Society for Microbiology.

4. That the International Committee shall select from its membership a Judicial Commission consisting of twelve members, exclusive of members *ex officio*, and shall designate a Chairman from the membership of the Commission. The two Permanent Secretaries of the International Committee on Bacteriological Nomenclature shall be members *ex officio* of the Judicial Commission. The Commissioners shall serve in three classes of four commissioners each for nine years, so that one class of four commissioners shall retire at every International Congress. In case of the resignation or death of any Commissioner, his place shall be filled for the unexpired term by the International Committee at its next meeting.

By prompt action at and subsequent to the Congress ballots were cast in spite of war conditions by 26 of the 62 members of the Permanent Committee on Nomenclature. These ballots when examined by the joint Secretaries of the Permanent Committee in November, 1942 were found to have resulted in the selection of the persons whose names appear below. These

are grouped in the three classes specified by the Permanent Committee, those receiving the highest number of votes being placed in the nine year class, those receiving the next highest in the six year class, etc. Names in the classes are arranged alphabetically.

Elected for nine years.—(The term normally expires in 1948.) R. E. Buchanan (U.S.A.), A. J. Kluyver (The Netherlands), E. G. D. Murray (Canada), S. Orla Jensen (Denmark): *Elected for six years.*—(Term normally expires in 1945.) J. Howard Brown (U.S.A.), A.-R. Prévot (France), J. Ramsbottom (Great Britain), Th. Thjötta (Norway); *Elected for three years.*—(Term normally would have expired in 1942.) A. Lwoff (France), R. Renaux (Belgium), A. Sordelli (Argentine), C. Stapp (Germany).

This announcement was made (Sci., *97*, 1943, 370) in the hope that some plan for taking tentative action on questions of nomenclature could be developed by those members of the Commission who could be reached under war conditions.

While no provision was made in 1939 for the contingencies that have arisen, it is felt that those elected should serve until successors are elected. Professor R. E. Buchanan has been asked to act as Chairman *pro tem* of the Judicial Commission as there is no possibility of securing an election under the rules as adopted.

Tentative International Rules of Bacteriological Nomenclature were presented to the Third International Congress of Microbiology by a U.S.A.-Canadian Committee on Compilation of Proposals on Bacteriological Nomenclature. As it proved impossible to give adequate consideration to these proposals during the Congress, the following recommendations of the Permanent Committee on Nomenclature were accepted:

1. That a recognized Bacteriological Code be developed.
2. That publication of such a proposed Code, when developed, be authorized with the proviso that it shall be regarded as wholly tentative, but in the hope that it shall be widely tested so that it may be brought up for further consideration and final disposition at the next Microbiological Congress which should normally take place in 1942.

Copies of this tentative Code have been issued in mimeographed form by Prof. R. E. Buchanan, Iowa State College, Ames, Iowa, U.S.A., Chairman of the U.S.A.-Canadian Committee and may be obtained from him.

CLASS SCHIZOMYCETES NÄGELI

(Bericht Verhandl. d. bot. Section d. 33 Versammling deutsch. Naturforsch. u. Arzt. Bot. Ztg., 1857, 760.)

Synonyms: *Bacteria* Cohn, Beitr. Biol. d. Pflanzen, *1*, Heft 1, 1872, 136; *Bacteriaceae* Cohn, *ibid.*, 237; *Bacteriales* Clements (as an ordinal name), The Genera of Fungi, Minneapolis, 1909, 8; *Schizomycetaceae* De Toni and Trevisan, in Saccardo, Sylloge Fungorum, 8, 1889, 923; *Schizomycetacea* Castellani and Chalmers, Manual of Tropical Medicine, 3rd ed., 1919, 924; *Mychota* Enderlein, Bakteriencyclogenie, 1924, 236; *Schizomycetae* Stanier and Van Niel, Jour. Bact., *42*, 1941, 458.

Typically unicellular plants. Cells usually small, sometimes ultramicroscopic. Frequently motile. As in the closely related blue-green algae (Class *Schizophyceae*), the cells lack the definitely organized nucleus found in the cells of higher plants and animals. However, bodies containing chromatin which may represent simple nuclei are demonstrable in some cases. Individual cells may be spherical; or straight, curved or spiral rods. These cells may occur in regular or irregular masses or even in cysts. Where they remain attached to each other after cell division, they may form chains or even definite filaments. The latter may show some differentiation into holdfast cells, and into motile or non-motile reproductive cells (conidia). Some grow as branching mycelial threads whose diameter is not greater than that of ordinary bacterial cells, i.e., about one micron. Some species produce pigments. The true purple and green bacteria possess pigments much like or related to the true chlorophylls of higher plants. These pigments have photosynthetic properties. The phycocyanin found in the blue green algae does not occur in the *Schizomycetes*. Multiplication is typically by cell division. Endospores are formed by some species included in *Eubacteriales*. Sporocysts are found in *Myxobacteriales*. Ultramicroscopic reproductive bodies are found in *Borrelomycetaceae*. The bacteria are free-living, saprophytic, parasitic or even pathogenic. The latter types cause diseases of either plants or animals. Seven orders are recognized.

Key to the Orders and Sub-Orders of the Class **Schizomycetes.**

A. Cells rigid, not flexuous. Motility by means of flagella or by a gliding movement.
  1. Cells single, in chains or masses. Not branching and mycelial in character. Not arranged in filaments. Not acid-fast. Motility when present by means of flagella.

     Order I. *Eubacteriales*, p. 66.

   a. Do not possess photosynthetic pigments. Cells do not contain free sulfur.
     b. Not attached by a stalk. Do not deposit ferric hydroxide.

       Sub-Order I. *Eubacteriineae*, p. 67.

     bb. Attached to substrate, usually by a stalk. Some deposit ferric hydroxide.

       Sub-Order II. *Caulobacteriineae*, p. 827.

   aa. Possesses photosynthetic chlorophyll-like pigments. Some cells contain free sulfur.

       Sub-Order III. *Rhodobacteriineae*, p. 838.

2. Organisms forming elongated usually branching and mycelial cells. Multiply by cell division, special spores, oidiospores and conidia. Sometimes acid-fast. Non-motile.

Order II. *Actinomycetales*, p. 895.

3. Cells in filaments frequently enclosed in a tubular sheath with or without a deposit of ferric hydroxide. Sometimes attached. Motile flagellate and non-motile conidia. Filaments sometimes motile with a gliding movement. Cells sometimes contain free sulfur.

Order III. *Chlamydobacteriales*, p. 981.

B. Cells flexuous, not rigid.

1. Cells elongate. Motility, by creeping on substrate.

Order IV. *Myxobacteriales*, p. 1005.

2. Cells spiral. Motility, free swimming by flexion of cells.

Order V. *Spirochaetales*, p. 1051.

Supplements: Groups whose relationships are uncertain.

1. Obligate intracellular parasites or dependent directly on living cells.
   a. Not ultramicroscopic and only rarely filterable. More than 0.1 micron in diameter.

   Group I. Order *Rickettsiales*, p. 1083.

   aa. Usually ultramicroscopic and filterable. Except for certain pox viruses of animals and a few plant viruses, less than 0.1 micron in diameter.

   Group II. Order *Virales*, p. 1128.

2. Grow in cell-free culture media with the development of polymorphic structures including rings, globules, filaments and minute reproductive bodies (less than 0.3 micron in diameter).

Group III. Family *Borrelomycetaceae*, p. 1291.

ORDER I. EUBACTERIALES BUCHANAN.

(Jour. Bact., *2*, 1917, 162.)

Simple and undifferentiated rigid cells which are either spherical or rod-shaped. The rods may be short or long, straight or curved or spiral. Some groups or species are non-motile, others show locomotion by means of flagella. Elongated cells divide by transverse fission and may remain attached to each other in chains. Spherical organisms divide either by parallel fission producing chains, or by fission alternating in two or three planes producing thus either tetrads or cubes of 8 and multiples of 8 cells. Many spherical cells form irregular masses in which the plane of division cannot be ascertained. Endospores occur in some species. Some species are chromogenic, but only in a few is the pigment photosynthetic (bacteriochlorophyll or other chlorophyll-like pigments).

A group of rather large, spherical to short rod-shaped, colorless sulfur bacteria, which some feel should be included in the order *Eubacteriales*, has been attached as an Appendix to the order *Chlamydobacteriales* on account of the physiological similarity between the former organisms and the *Beggiatoaceae*. These are in Family *Achromatiaceae*, p. 997.

SUB-ORDER I. **Eubacteriineae** BREED, MURRAY AND HITCHENS.

(Jour. Bact., *47*, 1944, 421.)

These are, as the name *Eubacteriinae* implies, the true bacteria in the narrower sense of the word. The cells are rigid and free. Branching occurs only under abnormal conditions of life. They are not attached by holdfasts nor stalks. They form no sheaths. One-third of the species form pigments, but these have no photosynthetic properties. Endospores occur in one family (*Bacillaceae*), rarely in others.

Key to the Families of the Sub-Order **Eubacteriineae.**

I. No endospores (except *Sporosarcina*).
  A. Can develop on inorganic media. Autotrophic and facultative autotrophic.
    Family I. *Nitrobacteriaceae*, p. 69.
  B. Cannot develop on inorganic media (exceptions, see Family XII. *Bacteriaceae*). Heterotrophic.
    1. Polar flagellate, straight, curved or spiral rods. Gram-negative. (Some species with a single flagellum will be found under Family IV. *Rhizobiaceae*, Family V. *Micrococcaceae* and Family VIII. *Corynebacteriaceae*).
      Family II. *Pseudomonadaceae*, p. 82.
    2. Large, oval, pleomorphic cells sometimes almost yeast-like in appearance. Free living in soil. Fix free nitrogen. Peritrichous flagellation.
      Family III. *Azotobacteriaceae*, p. 219.
    3. Peritrichous or non-motile rods, and cocci.
      a. Heterotrophic rods which may not require organic nitrogen for growth. Usually motile with one to six or more flagella. Usually form nodules or tubercles on roots of plants, or show violet chromogenesis.
        Family IV. *Rhizobiaceae*, p. 223.
      aa. Heterotrophic rods or cocci which utilize organic nitrogen and usually carbohydrates.
        b. Spherical cells in masses, tetrads, and packets. A few species are motile with one or two flagella.
          c. Gram-positive to Gram-negative cocci. Not obligate parasites.
            Family V. *Micrococcaceae*, p. 235.
          cc. Gram-negative, and sometimes anaerobic cocci. Obligate parasites.
            Family VI. *Neisseriaceae*, p. 295.
        bb. Spherical cells which grow in pairs and chains; and rods.
          c. Gram-positive cocci and rods. Non-motile (some species of *Streptococcaceae* or *Corynebacteriaceae* may show motility).
            d. Microaerophilic to anaerobic cocci and rods. Frequently in chains. Active in the fermentation of sugars. Never reduce nitrates.
              Family VII. *Lactobacteriaceae*, p. 305.
            dd. Usually aerobic, but sometimes anaerobic rods. Less active in the fermentation of sugars. May or may not reduce nitrates.
              Family VIII. *Corynebacteriaceae*, p. 381.

cc. Gram-negative rods. When motile, from four to many peritrichous flagella.

d. Grow well on ordinary media containing peptone. Aerobic to facultative anaerobic.

e. Gram-negative, straight rods which ferment sugars with the formation of organic acids.

f. Produce little or no acid in litmus milk. May or may not reduce nitrates. Many yellow chromogens. Borderline between this and following family indistinct. Some species anaerobic.

Family IX. *Achromobacteriaceae*, p. 412.

ff. Produce CO_2 and frequently visible gas (CO_2 + H_2) from glucose. Reduce nitrates. Usually from the alimentary, respiratory or urinary tract of vertebrates, though some are free-living or even plant parasites.

Family X. *Enterobacteriaceae*, p. 443.

dd. Small Gram-negative rods. Obligate parasites which usually require body fluids for growth. Do not grow well on ordinary media. Some are anaerobic.

Family XI. *Parvobacteriaceae*, p. 545.

ccc. Rods of varied types not included in above families. Aerobic to facultative anaerobic.

Family XII. *Bacteriaceae*, p. 596.

II. Form endospores. Large rods, sometimes in chains. Aerobic to anaerobic.

Family XIII. *Bacillaceae*, p. 704.

*FAMILY I. NITROBACTERIACEAE BUCHANAN

(Jour. Bact., *2*, 1917, 349 and Jour. Bact., *3*, 1918, 179.)

Cells without endospores. Rod-shaped or ellipsoidal except for one spherical species (*Nitrosococcus nitrosus*). Spiral rods in *Nitrosospira* and in one species of *Thiobacillus*. Flagella either polar (so far as known), or absent. Gram stain uncertain, but presumably Gram-negative for all of the polar flagellate, rod-shaped species except for *Nitrosomonas monocella* which is reported to be Gram-positive. Capable of growing without organic compounds, using CO_2 as the source of carbon, and obtaining their energy by oxidation of ammonia, nitrite, hydrogen, sulfur, or thiosulfate. Some species can also utilize organic compounds. Non-parasitic, usually soil or water forms.

Key to the tribes and genera of family **Nitrobacteriaceae.**

A. Organisms oxidize ammonia to nitrite, or nitrite to nitrate. Growth on standard media very poor or absent.
Tribe I. *Nitrobacterieae*, p. 70.
 a. Cells oxidize ammonia to nitrite.
  b. Cells are separate, free or in dense aggregates. Do not form zoogloea.
   c. Cells ellipsoidal.
Genus I. *Nitrosomonas*, p. 70.
   cc. Cells spherical.
Genus II. *Nitrosococcus*, p. 71.
   ccc. Cells spiral.
Genus III. *Nitrosospira*, p. 71.
  bb. Cells form a zoogloea.
   c. The zoogloea is surrounded by a common membrane forming a cyst.
Genus IV. *Nitrosocystis*, p. 72.
   cc. The massed cells are embedded in slime. No common membrane surrounds the cells.
Genus V. *Nitrosogloea*, p. 73.
 aa. Cells oxidize nitrite to nitrate.
  b. Cells form no zoogloea.
Genus VI. *Nitrobacter*, p. 74.
  bb. Cells form a zoogloea.
Genus VII. *Nitrocystis*, p. 75.

B. Organisms oxidize hydrogen.
Tribe II. *Hydrogenomonadeae*, p. 76.
 a. Aerobic, non-spore-forming rods with single polar flagellum, or non-motile.
Genus I. *Hydrogenomonas*, p. 76.

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* Text revised by Prof. R. S. Breed and Prof. H. J. Conn, Geneva, N. Y., Dec., 1937. Completely revised by Dr. R. L. Starkey, New Jersey Agricultural Experiment Station, New Brunswick, N. J., March, 1943.

C. Organisms oxidize sulfur or thiosulfate and similar inorganic compounds of sulfur.

Tribe III. *Thiobacilleae*, p. 78.

a. Aerobic to anaerobic, non-spore-forming rods with a single polar flagellum on each (so far as known), or non-motile.

Genus I. *Thiobacillus*, p. 78.

TRIBE I. NITROBACTERIEAE WINSLOW ET AL.

(Jour. Bact., *5*, 1920, 201.)

Organisms deriving energy from the oxidation of ammonia to nitrite or from nitrite to nitrate and depend on this oxidation for growth. Fail to grow on media containing organic matter in the absence of the specific inorganic materials used as sources of energy. Many organic compounds commonly used in standard culture media are toxic to this group.

Genus I. Nitrosomonas *Winogradsky.*

(*Nitromonas* Winogradsky, Ann. Inst. Past., *4*, 1890, 257; Arch. Sci. biol., St. Petersburg, *1*, 1892, 127; *emend.* S. and H. Winogradsky, Ann. Inst. Past. *50*, 1933, 350.)

Cells ellipsoidal, non-motile or with a single polar flagellum, occurring singly, in pairs, short chains or irregular masses, which are not enclosed in a common membrane. Oxidize ammonia to nitrite more rapidly than the other genera of this tribe. From Latin, *nitrosus*, full of soda; M.L. *nitrous*; and Greek *monas*, a unit; M.L. a monad.

The type species is *Nitrosomonas europaea* Winogradsky.

1. **Nitrosomonas europaea** Winogradsky. (Arch. Sci. biol., St. Petersburg, *1*, 1892, 127; *Bacterium nitrosomonas* Lehmann and Neumann, Bakt. Diag., 2nd ed., *2*, 1899, 187; *Pseudomonas europaea* Migula, in Engler and Prantl, Die natürl. Pflanzenfam., *1*, 1a, 1895, 29; *Planococcus europaeus* Vuillemin, Ann. Mycologie, Berlin, *11*, 1913, 525.) From Latin, *europaeus*, of Europe.

Rods: 0.9 to 1.0 by 1.1 to 1.8 microns occurring singly, rarely in chains of three to four. Possess a single polar flagellum 3 to 4 times the length of the rods, or rarely one at either end.

Grow readily in aqueous media without organic matter, and containing ammonium sulfate, potassium phosphate, and magnesium carbonate. The cells accumulate in soft masses around the particles of magnesium carbonate at the bottom of the flask. The liquid is occasionally turbid through development of motile swarmer cells or monads.

Small, compact, sharply defined colonies brownish in color on silica gel.

Aerobic.

Strictly autotrophic.

Source: Soils of Zurich, Switzerland; of Gennevilliers, France; and Kazan, Russia.

Habitat: Presumably widely distributed in soil.

1a. *Nitrosomonas europaea* var. *italica* Perotti (Rendic. d. Accad. d. Lincei Roma, *15*, 1906, 516; Abs. in Cent. f. Bakt., II Abt., *19*, 1907, 337). Also see Engel and Skallau (Cent. f. Bakt., II Abt., *97*, 305, 1937).

2. **Nitrosomonas monocella** Nelson. (Cent. f. Bakt., II Abt., *83*, 1931, 287.) From Greek *monos*, single and Latin *cella*, room; M.L. single cell.

Ovoid rods: 0.6 to 0.9 micron, often occurring in pairs. Young cells nearly spherical. Motile by means of a single

polar flagellum 3 to 5 times as long as the rod. Gram-positive (Nelson). Found negative by H. J. Conn (personal communication).

No growth in nutrient broth, nutrient agar, nutrient or plain gelatin, plain or litmus milk, glucose or plain yeast water, or on potato.

Silica gel or agar plates of inorganic medium: No typical colonies, but yellowish brown masses of growth around particles of $CaCO_3$ in the medium.

Inorganic liquid medium containing ammonium salts: Uniform development throughout the liquid as well as in the carbonate sediment.

Even low concentrations of organic matter retard or completely inhibit the initiation of growth. Plant extracts are toxic.

Free CO_2 and O_2 necessary for growth.

Optimum pH 8.0 to 9.0. Poor growth below pH 7.0. Some growth above pH 9.0.

Optimum temperature for growth and oxidation 28°C.

Aerobic.

Strictly autotrophic.

Source: Isolated from field soil.

Habitat: Presumably widely distributed in soil.

S. Winogradsky and H. Winogradsky (Ann. Inst. Pasteur, *50*, 1933, 394) have described 5 cultures of *Nitrosomonas* which were obtained from soils of France. An additional culture has been described by H. Winogradsky (Ann. Inst. Pasteur, *58*, 1937, 394) from activated sludge.

Genus II. **Nitrosococcus** *Winogradsky.*

(Arch. Sci. biol., St. Petersburg, *1*, 1892, 127.)

Cells large spheres, non-motile, not producing zoogloea. Oxidize ammonia to nitrite. From Latin, *nitrosus*, full of soda; and Greek *kokkos*, grain; M.L. nitrous coccus.

The type species is *Nitrosococcus nitrosus* (Migula) Bergey et al.

1. **Nitrosococcus nitrosus** (Migula) Bergey et al. (*Nitrosococcus* Winogradsky, Ann. Inst. Pasteur, *5*, 1891, 577; Arch. Sci. biol., St. Petersburg, *1*, 1892, 127; *Micrococcus nitrosus* Migula, Syst. d. Bakt., *2*, 1900, 194; *Nitrosococcus americanus* Buchanan, Jour. Bact., *3*, 1918, 180; Manual, 2nd ed., 1925, 35.) From Latin, *nitrous*, full of soda; M.L. nitrous.

Large spheres, 1.5 to 1.7 microns in size, with thick cell membrane. Motility could not be demonstrated. Stains readily with aniline dyes. Observed no zoogloea formation. Gram-positive (Omelianski, Cent. f. Bakt., II Abt., *19*, 1907, 263).

Liquid medium: Turbidity.

Silica gel: Both dark and light colonies. Surface colonies look like small drops of a turbid yellowish liquid.

Aerobic.

Optimum temperature 20° to 25°C.

Source: Isolated from soil from Quito, Ecuador; Companias, Brazil; Melbourne, Australia.

Habitat: Presumably widely distributed in soil.

Genus III. **Nitrosospira** *Winogradsky.*

(Compt. rend. Acad. Sci., Paris, *192*, 1931, 1004; Ann. Inst. Pasteur, *50*, 1933, 406.)

Cells spiral-shaped. Oxidize ammonia to nitrite very slowly. From Latin, *nitrosus*, full of soda; and *spira*, coil, spiral; M.L. nitrous spiral.

The type species is *Nitrosospira briensis* Winogradsky.

1. **Nitrosospira briensis** Winogradsky. (Ann. Inst. Pasteur, *50*, 1933, 407.) From French, *Brie*, a place name; M.L. of Brie.

Spirals wound tightly to form very small cylinders as long as 15 to 20 microns. Short spirals have the appearance of short rods and ellipsoidal cells. Small pseudo-cocci were observed in old cultures.

Colonies on silica gel: Small colonies which occasionally contain cyst-like aggregates of cells. The cysts are more poorly developed than in *Nitrosocystis*.

Aerobic.

Reaction optimum: pH 7.0 to 7.2.

Source: Uncultivated pasture soil of Brie, France.

Habitat: Presumably widely distributed in soil.

2. **Nitrosospira antarctica** Winogradsky. (Ann. Inst. Pasteur, *50*, 1933, 407.) From Greek, *antarkitos*, southern, antarctic.

Cells and colonies similar to *N. briensis* except that the cells are generally wound together to form more compact spirals.

Aerobic.

Reaction optimum: pH 7.0 to 7.2

Source: Soil from the Antarctic.

Habitat: Presumably widely distributed in soil.

Genus IV. Nitrosocystis *Winogradsky.*

(Compt. rend. Acad. Sci., Paris, *192*, 1931, 1003; Ann. Inst. Pasteur, *50*, 1933, 399.)

Cells ellipsoidal or elongated, uniting in compact, rounded aggregates surrounded by a common membrane to form cysts. The cysts disintegrate to free the cells, particularly when transferred to fresh media. Within the cyst, the cells are embedded in slime. Oxidize ammonia to nitrite at a rate intermediate between *Nitrosomonas* and *Nitrosospira*. From Latin, *nitrosus*, full of soda; and Greek, *kystis*, bladder; M.L. nitrous cyst.

The type species is *Nitrosocystis javanensis comb. nov.*

1. **Nitrosocystis javanensis** *comb. nov.* (*Nitrosomonas javanensis* Winogradsky, Arch. Sci. biol., St. Petersburg, *1*, 1892, 127; *Pseudomonas javanensis* Migula, in Engler and Prantl, Die natürl. Pflanzenfam., *1*, 1a, 1895, 30; Compt. rend. Acad. Sci., Paris, *192*, 1931, 1003.) From Latin, of Java.

Small ellipsoidal cells having a diameter of 0.5 to 0.6 micron. Possess a polar flagellum 20 times as long as the rods.

In liquid medium produces very compact zoogloeal masses of cells and motile swarmers. The large zoogloea are themselves composed of smaller compact aggregates of cells.

On silica gel the colonies are circular to elliptical becoming clear or light brown.

Aerobic.

Strictly autotrophic.

Source: Soil of Buitenzorg, Java; Tokyo, Japan; La Reghaia, Tunisia.

Habitat: Presumably widely distributed in soil.

2. **Nitrosocystis coccoides** *nom. nov.* (*Nitrosocystis a*, S. Winogradsky and H. Winogradsky, Ann. Inst. Pasteur, *50*, 1933, 401.) From Greek, *kokkos*, a grain; *cidos*, form, shape; M.L. coccus-like.

Ellipsoidal cells about 1.5 microns in diameter. Occur as compact aggregates of cells imbedded in mucus and surrounded by a thickened capsule to form cyst-like bodies. Cells rarely solitary but more often in pairs and in small groups of four or more. Probably motile. The mucus which surrounds the cells is not readily stained, whereas the outside coating stains more easily.

Colonies on silica gel: As colonies develop, the coating of $CaCO_3$ on the gel becomes yellowish and dissolves and the

colony appears as a bulbous, angular, brown body which may become 0.5 mm. in diameter. The cells are held firmly together in these irregularly shaped bulbous aggregates.

Aerobic.

Source: Poor soils of Brie and elsewhere in France.

Habitat: Presumably widely distributed in forest and manured soils.

A similar culture called *Nitrosocystis B.A.* was isolated from activated sludge by H. Winogradsky (Compt. rend. Acad. Sci., Paris, *200*, 1935, 1888; Ann. Inst. Pasteur, *58*, 1937, 326). It produced compact, bulbous, dented cyst-like aggregates of cells having a yellow color. The colonies produced clear zones on silica gel coated with $CaCO_3$. These cysts were composed of oval or elongated coccoid cells imbedded in mucus and surrounded by a thickened capsule, composed of two layers. The cells become dispersed from the cysts as motile cells and form new colonies. This culture differs from *N. coccoides* in that the colonies have a pale reddish yellow color and the oval cells are 0.5 by 1.5 microns in size.

Cultures of *Nitrosocystis* were obtained by Rommell (Svensk. botan. Tidskrift, *26*, 1932, 303) from forest soils. Kingma Boltjes (Arch. f. Mikrobiol., *6*, 1935, 79) obtained cultures which produced masses of cells, some of which were loose and others compact. They were not believed to be true zoogloea since no capsule or slimy substance was noted. The development of true cysts by nitrifying bacteria was questioned. Winogradsky (Bull. d. l'Inst. Pasteur, *33*, 1935, 1074) concluded that Kingma Boltjes worked with a culture of *Nitrosocystis* and not of *Nitrosomonas* as was believed.

Genus V. **Nitrosogloea** *H. Winogradsky.*

(Compt. rend. Acad. Sci., Paris, *200*, 1935, 1887; Ann. Inst. Pasteur, *58*, 1937, 335.)

Cells ellipsoidal or rod-shaped. Embedded in slime to form zoogloea. No common membrane surrounds the cells aggregates. Oxidize ammonia to nitrite. From Latin, *nitrosus*, full of soda; and Greek, *gloea*, glue, jelly; M.L. nitrous jelly.

The type species is *Nitrosogloea merismoides* H. Winogradsky.

1. **Nitrosogloea merismoides** H. Winogradsky. (*Nitrosocystis "I"*, H. Winogradsky, Trans. Third Intern. Cong. Soil Sci., Oxford, *1*, 1935, 139; Compt. rend. Acad. Sci., Paris, *200*, 1935, 1887; Ann. Inst. Pasteur, *58*, 1937, 333.) From Greek, *merismos*, a dividing, division; *eidos*, form, shape; M.L. division-like.

Ellipsoidal cells: 0.5 by 1.5 microns. Oval cells or short rods forming tetrads or chains, each group with its own sheath. The groups vary in shape to produce branched chains, irregular or compact aggregates.

Colonies on silica gel: Cells encased in a pale yellow mucilage giving the colony a dull appearance. Colony surface studded with little humps.

Aerobic.

Source: Activated sludge.

Habitat: Unknown.

2. **Nitrosogloea schizobacteroides** H. Winogradsky. (*Nitrosocystis "II"*, H. Winogradsky, Trans. Third Intern. Cong. Soil Sci., Oxford, *1*, 1935, 139; Compt. rend. Acad. Sci., Paris, *200*, 1935, 1887; Ann. Inst. Pasteur, *58*, 1937, 333.) From Greek, *schizo*, to split; *bakterion*, a small rod; *eidos*, form, shape; M.L. like a dividing rod.

Rods: Elongated rods or short filaments 3 to 4 microns long.

Colonies on silica gel: Flat groups of cells are produced which are united in a common sheath. The aggregates form a

pseudo-tissue of interwoven filaments suggestive of a fungus pad. The pad can be removed as a unit from the medium.

Aerobic.

Source: Activated sludge.

Habitat: Unknown.

3. **Nitrosogloea membranacea** H. Winogradsky. (*Nitrosocystis "III"*, H. Winogradsky, Trans. Third Intern. Cong. Soil Sci., Oxford, *1*, 1935, 139; Compt. rend. Acad. Sci., Paris, *200*, 1935, 1887; Ann. Inst. Pasteur, *58*, 1937, 333.) From Latin, *membranaceus*, of skin or membrane.

Ellipsoidal cells commonly in pairs and also solitary.

Colonies on silica gel: Appear as dull mucoid material with a pale straw color. The cells are held firmly together so that the entire colony is easily picked up with the transfer needle. No structural units within the colony.

Aerobic.

Source: Activated sludge.

Habitat: Unknown.

Genus VI. **Nitrobacter** *Winogradsky.*

(Winogradsky, Arch. Sci. biol., St. Petersburg, *1*, 1892, 127; *Nitromonas* Orla-Jensen, Cent. f. Bakt., II Abt., *22*, 1909, 334; not *Nitromonas* Winogradsky, Ann. Inst. Past., *4*, 1890, 257; *Nitrobacterium* Castellani and Chalmers, Manual Trop. Med., 1919, 933.)

Cells rod-shaped. Oxidize nitrite to nitrate. From Latin, *nitrum*, soda; M.L. nitre; and Greek *baktron*, a small rod.

The type species is *Nitrobacter winogradskyi* Buchanan.

1. **Nitrobacter winogradskyi** Buchanan. (*Nitrobacter* Winogradsky, Arch. Sci. biol., St. Petersburg, *1*, 1892, 127; *Bacterium nitrobacter* Lehmann and Neumann, Bakt. Diag., 2nd ed., *2*, 1899, 187; *Bacillus nitrobacter* Löhnis, Vorlesungen landw. Bakt., Berlin, 1913, 152; Buchanan, Jour. Bact., *3*, 1918, 180; *Nitrobacterium nitrobacter* Castellani and Chalmers, Manual Trop. Med., 1919, 933.) Named for S. Winogradsky, 1856– , the Russian microbiologist, who first isolated these bacteria.

Description taken from Gibbs, Soil Sci., *8*, 1919, 448.

Short, non-motile rods with gelatinous membrane, 0.6 to 0.8 by 1.0 to 1.2 microns. Does not stain readily. Gram-negative (Omelianski, Cent. f. Bakt., II Abt., *19*, 1907, 263.)

Can be cultivated on media free of organic matter. Sensitive to certain organic compounds.

Washed agar colonies: In 7 to 10 days very small, light brown, circular to irregular colonies, becoming darker.

Silica gel: Colonies smaller but more dense than on washed agar.

Washed agar slant: In 7 to 10 days scanty, grayish streak.

Inorganic solution medium: After 10 days flocculent sediment. Sensitive to ammonium salts under alkaline conditions.

Nitrite is oxidized to nitrate.

Aerobic.

Strictly autotrophic.

Optimum temperature 25° to 28°C.

Source: Soil.

Habitat: Presumably widely distributed in soil.

2. **Nitrobacter agile** Nelson. (Cent. f. Bakt., II Abt., *83*, 1931, 287.) From Latin *agile*, quick, agile, motile.

Rods: 0.5 by 0.8 to 0.9 micron, occurring singly, sometimes in pairs or larger aggregates. Rapidly motile with a long, thin, polar flagellum often 7 to 10 times as long as the rod. (Non-motile culture obtained by Kingma Boltjes, Arch. f. Mikrobiol., *6*, 1935, 79.) Gram-negative.

No growth in nutrient broth, nutrient agar, nutrient or plain gelatin, litmus or plain milk, glucose or plain yeast water, or on potato.

Nitrite agar: After two weeks, produces semi-spherical, minute, nearly transparent colonies. Oxidation usually complete in 10 to 14 days.

Inorganic liquid medium containing nitrite: Produces uniformly dispersed growth.

Optimum pH 7.6 to 8.6. Limits of growth 6.6 to 10.0.

Temperature relations: Optimum for growth 25° to 30°C. Optimum for oxidation 28°C. No oxidation at 37°C. Thermal death point 60°C. for five minutes.

Strictly autotrophic.

Aerobic.

Source: Isolated from greenhouse soils and from sewage effluents in Madison, Wisconsin.

Habitat: Presumably widely distributed in soil.

Genus VII. **Nitrocystis** *H. Winogradsky.*

(Trans. Third Intern. Cong. Soil Sci., Oxford, *1*, 1935, 139; *Nitrogloea* H. Winogradsky, Comp. rend. Acad. Sci., Paris, *200*, 1935, 1888.)

Cells ellipsoidal or rod-shaped. Embedded in slime and united into compact zoogloeal aggregates. Oxidize nitrite to nitrate. From Latin, *nitrum*, soda; M.L. *nitre;* and Greek, *kystis*, bladder; M.L. nitric cyst.

The type species is *Nitrocystis sarcinoides*.

1. **Nitrocystis sarcinoides** H. Winogradsky. (*Nitrocystis B. A.*, Winogradsky, H., Compt. rend. Acad. Sci., Paris, *200*, 1935, 1888; *Nitrocystis "I"* and *"II"*, Winogradsky, H., Trans. Third Intern. Cong. Soil Sci., Oxford, *1*, 1935, 139; Ann. Inst. Pasteur, *58*, 1937, 336.) From Latin, *sarcina*, a packet; M.L. *Sarcina*, a genus; Greek, *eidos*, form; M.L. *Sarcina*-like.

Rods: Small rods 0.5 by 1.0 micron. Cells ellipsoidal or wedge-shaped and grouped in sarcina-like packets.

Colonies on silica gel: On the surface of gel coated with kaolin the colonies appear as small raised amber warts. The colonies grow up to 5 mm. in diameter. The colonies are viscous and sticky when young and they become brown with age, shrink, and look like scales and become hard like grains of sand. Each colony is enveloped in several layers of a thick slime which holds the cells together so that the entire colony can be removed with a transfer needle.

Aerobic.

Source: Activated sludge.

Habitat: Unknown.

2. **Nitrocystis micropunctata** H. Winogradsky. (*Nitrocystis "III"*, Winogradsky, H., Trans. Third Intern. Cong. Soil Sci., Oxford, *1*, 1935, 139; *Nitrogloea micropunctata* Winogradsky, H., Compt. rend. Acad. Sci., Paris, *200*, 1935, 1888; Ann. Inst. Pasteur, *58*, 1937, 326.) From Greek, *mikros*, small, little; and Latin, *punctatus*, spotted; M.L. with small spots.

Cells are ellipsoidal rods about 0.5 micron in diameter which stain poorly except at the ends. Encased in a viscous slime.

Colonies on silica gel: Like *N. sarcinoides* except that the colonies are more clear and they have a more plastic consistency. The cells are not held together by the slime in the colony as with *N. sarcinoides*. The capsule is more readi'y differentiated in old colonies.

Aerobic.

Source: Activated sludge.

Habitat: Unknown.

Appendix: The following have been placed in the Tribe *Nitrobacterieae*, sometimes incorrectly so:

Bactoderma alba Winogradsky. (Ann.

Inst. Pasteur, *50*, 1933, 414.) From soil. This is the type species of genus *Bactoderma* Winogradsky.

Bactoderma rosea Winogradsky (*loc. cit.*, p. 415). Isolated from soil.

Bacterium nitrificans Chester. (Nitratbildner aus Northeim, Burri and Stutzer, Cent. f. Bakt., II Abt., *1*, 1895, 735; Chester, Ann. Rept. Del. Col. Agr. Exp. Sta., *9*, 1897, 94; *Bacillus nitrificans* Chester Man. Determ. Bact., 1901, 239; *Achromobacter nitrificans* Bergey et al., Manual, 1st ed., 1923, 137.) From soil. Description of this organism was shown by Winogradsky (Cent. f. Bakt., II Abt., *2*, 1896, 415 and 449) to have been based on impure cultures.

Microderma minutissima Winogradsky. From soil. This is the type species of genus *Microderma* Winogradsky.

Microderma vacuolata Winogradsky (*loc. cit.*). Isolated from soil.

Nitrosobacillus thermophilus Campbell. See *Bacillus* appendix.

Nitrobacter flavum Sack. (Cent. f. Bakt., II Abt., *62*, 1924, 20.) Isolated from garden earth. See description, Manual, 5th ed., 1939, 74. Heterotrophic and does not belong here (Kingma Boltjes, Arch. f. Mikrobiol., *6*, 1935, 83).

Nitrobacter oligotrophum Beijerinck. (Folia Microbiol., *3*, 1914, 91; Verzamelde Geschriften van M. W. Beijerinck, *5*, 1922, 190.) Isolated from soil. On cultivation this species lost its autotrophic habit and became heterotrophic. The organism was then called *Nitrobacter polytrophum* Beijerinck.

Nitrobacter opacum Sack (*loc. cit.* p. 21). Source and relationships as above. See Manual, 5th ed., 1939, 75.

Nitrobacter punctatum Sack (*loc. cit.*, p. 20). Source and relationships as above. See Manual, 5th ed., 1939, 75.

Nitrobacter roseo-album Sack (*loc. cit.*, p. 17; *Serratia roseo-alba* Bergey et al., Manual, 3rd ed., 1930, 125.) Source and relationships as above. See description, Manual, 5th ed., 1939, 74.

Nitrosomonas groningensis Sack. (Cent. f. Bakt., II Abt., *64*, 1925, 34.) Source and relationships as above. See description, Manual, 5th ed., 1939, 77.

TRIBE II. HYDROGENOMONADEAE PRIBRAM.

(Jour. Bact., *18*, 1929, 370.)

Short rods, non-motile or with lophotrichous flagella. Organisms capable of deriving energy from oxidation of hydrogen. They probably grow well on organic media without hydrogen, although this has not been shown to be true for all species.

Genus I. **Hydrogenomonas** *Orla-Jensen.**

(Cent. f. Bakt., II Abt., *22*, 1909, 311.)

As the only genus of the tribe, its definition is identical with the definition of the tribe. From Greek *hydōr*, water; *genos*, producing and *monas*, a unit.

The type species is *Hydrogenomonas pantotropha* (Kaserer) Orla-Jensen.

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* This group of bacteria is characterized by the ability to grow in substrates containing no organic matter and to utilize elemental hydrogen as the source of energy for growth. Under these conditions CO_2 is used as the source of carbon. Bacteria with similar physiological characteristics but differing in morphology are placed in the genera *Bacterium*, *Bacillus* and *Clostridium*. Although other bacteria and even certain algae have enzyme systems which can activate hydrogen and reduce CO_2 in the process, there is no evidence that these organisms are able to grow in inorganic media with hydrogen as the exclusive source of energy (See: Stephenson and Stickland, Biochem. Jour., *25*, 1931, 205, 215; Woods, Biochem. Jour., *30*, 1936, 515; Lee and Umbreit, Cent. f. Bakt., II Abt., *101*, 1940, 354; Gaffron, Amer. Jour. Bot., *27*, 1940, 273).

Key to the species of genus **Hydrogenomonas.**

A. Not sensitive to high O_2 concentrations. Growth in solution media under autotrophic conditions characterized by turbidity without pellicle formation.
1. *Hydrogenomonas pantotropha.*

B. Sensitive to high O_2 concentrations. Growth in solution media under autotrophic conditions characterized by pellicle adhering to walls of container.
2. *Hydrogenomonas vitrea.*

C. Sensitive to high O_2 concentrations. Growth in solution media under autotrophic conditions without pellicle formation.
3. *Hydrogenomonas flava.*

1. **Hydrogenomonas pantotropha** (Kaserer) Orla-Jensen. (*Bacillus pantotrophus* Kaserer, Cent. f. Bakt., II Abt., *16*, 1906, 688; Orla-Jensen, Cent. f. Bakt., II Abt., *22*, 1909, 311.) From Greek *pantos*, everything and *trophos*, feeds on; M.L. omnivorous.

Rods: 0.4 to 0.5 by 1.2 to 1.5 microns with rounded ends. Occur singly, in pairs, and in chains. Encapsulated. Actively motile by means of a single long polar flagellum. Gram stain not recorded. Bipolar staining in old cultures.

Inorganic solution: When cultivated under an atmosphere of O_2, CO_2 and H_2, the liquid becomes turbid without pellicle formation.

Inorganic solid media: When cultivated under an atmosphere of O_2, CO_2 and H_2, the colonies are yellow and slimy, and the agar plates have an odor resembling hot soapy water.

Gelatin colonies: Yellow, smooth, rarely concentrically ringed or greenish.

Gelatin stab: Growth only at surface. As a rule no liquefaction.

Agar colonies: Same as on gelatin, greenish, often slimy.

Broth: Turbid, somewhat slimy, and occasional pellicle.

Milk: No coagulation. A yellow pellicle forms. Medium becomes slimy and assumes a dirty flesh color.

Potato: Moist, yellow, glistening.

Indole is not formed.

Hydrogen sulfide is not formed.

Nitrite is not produced from nitrate.

Does not act on carbohydrates.

Aerobic.

Optimum temperature 28° to 30°C.

Facultative autotroph.

Distinctive characters: Develops autotrophically in inorganic medium under an atmosphere of H_2, O_2 and CO_2. Oxidizes hydrogen to water and uses CO_2 as the source of carbon for growth.

Source: Isolated from soil near Vienna.

Habitat: Probably widely distributed in soil.

2. **Hydrogenomonas vitrea** Niklewski. (Jahrb. f. wissensch. Botanik, *48*, 1910, 113). From Latin *vitreus*, of glass, transparent.

Rods: 2.0 microns in length, cells adhering to each other as by slime. Motility not observed.

Agar colonies on inorganic medium in presence of H_2, O_2 and CO_2: Delicate, transparent, with slight fluorescence, and yellow center. Surface folded. Do not develop readily beneath the surface of medium.

Agar streak on inorganic substrate: Same as agar colonies except that growth is spreading.

Inorganic liquid medium in presence of H_2, O_2 and CO_2: Pellicle, adherent to wall of tube. Good development when there is from 2 to 8 per cent oxygen in the gas. At higher O_2 concentrations good growth occurs only in association with *H. flava* or other bacteria.

Oxidizes hydrogen to water.

Microaerophilic, growing in an atmosphere of low oxygen tension, not exceeding 8 per cent.

Facultative autotroph.

Distinctive characters: Grows in substrates containing no organic matter and produces a pellicle.

Source: Isolated from mud, garden soil, pasture land, vegetable mold, and peat.

Habitat: Presumably widely distributed in soil.

3. **Hydrogenomonas flava** Niklewski. (Jahrb. f. wissensch. Botanik., *48*, 1910, 113; emend. Kluyver and Manten, Antonie v. Leuwenhoek, *8*, 1942, 71.) From Latin *flavus*, yellow.

Rods: 1.5 microns in length. Motility by polar flagella. Gram-negative.

Agar colonies on inorganic medium in presence of H_2, O_2 and CO_2: Small, smooth, yellow, shining, adhering to medium. Develop well below surface of medium, but growth is paler.

Gelatin not liquefied.

Inorganic liquid medium in presence of H_2, O_2, and CO_2: No pellicle formation. Good development when there is from 2 to 8 per cent oxygen in the gas. At higher O_2 concentrations good growth occurs only in association with *H. vitrea* or other bacteria.

Oxidizes hydrogen to water.

Microaerophilic, growing in an atmosphere of low oxygen tension, not exceeding 8 per cent.

Facultative autotroph.

Distinctive characters: Found singly on slides whereas the rod-shaped cells of *Hydrogenomonas vitrea* tend to cling together in masses. Colonies on agar opaque, not transparent.

Source: Same as *H. vitrea*.

Habitat: Presumably widely distributed in soil.

Appendix: Incompletely described species are found in the literature as follows:

Hydrogenomonas agilis Niklewski. (Jubliäumsschrift f. Prof. E. Godlewski. Kosmos, Lemberg, 1913; See Cent. f. Bakt., II Abt., *40*, 1914, 430.) From soil.

Hydrogenomonas minor Niklewski. (Jubliäumsschrift f. Prof. E. Godlewski. Kosmos, Lemberg, 1913; See Cent. f. Bakt., II Abt., *40*, 1914, 431.) From soil.

TRIBE III. THIOBACILLEAE BERGEY, BREED AND MURRAY.

(Preprint, Manual, 5th ed., Oct., 1938, v.)

Organisms capable of deriving their energy from oxidation of sulfur or sulfur compounds. Most species do not grow on organic media.

Genus I. Thiobacillus *Beijerinck.*

(Beijerinck, Cent. f. Bakt., II Abt., *11*, 1904, 593; *Sulfomonas* Orla-Jensen, Cent. f. Bakt., II Abt., *22*, 1909, 314; not *Thiobacillus* Ellis, Sulphur bacteria, London, 1932, 130; *Thiobacterium* Lehmann and Neumann, Bakt. Diag., 7 Aufl., *2*, 1927, 517; not *Thiobacterium* Janke, Allgemeine Tech. Mikrobiol., *1*, 1924, 68, Leipzig.)

Small Gram-negative, rod-shaped cells. Non-motile or motile by means of a single polar flagellum. Derive their energy from the oxidation of incompletely oxidized sulfur compounds, principally from elemental sulfur and thiosulfate but in some cases also from sulfide, sulfite, and polythionates. The principal product of oxidation is sulfate, but sulfur is sometimes formed. They grow under acid or alkaline conditions and derive their carbon from carbon dioxide or from bicarbonates in solution; some are obligate and some facultative autotrophic. One species is facultative anaerobic. From Greek *theion*, sulfur and Latin *bacillus*, a small rod.

The type species is *Thiobacillus thioparus* Beijerinck.

Key to the species of genus **Thiobacillus.**

I. Aerobic.
  A. Strictly autotrophic.
    1. Optimum reaction for growth close to neutrality.
      1. *Thiobacillus thioparus.*
    2. Optimum reaction for growth pH 2.0 to 3.5.
      2. *Thiobacillus thiooxidans.*
  B. Facultative autotrophic.
      3. *Thiobacillus novellus.*
      4. *Thiobacillus coproliticus.*

II. Anaerobic in presence of nitrate.
      5. *Thiobacillus denitrificans.*

1. **Thiobacillus thioparus** Beijerinck. (Cent. f. Bakt., II Abt., *11*, 1904, 593; Nathanson, Mitt. Zool. Station Neapel, *15*, 1902, 655; *Sulfomonas thioparus* Orla-Jensen, Cent. f. Bakt., II Abt., *22*, 1909, 326). From Greek *theion*, sulfur and *paro*, to make.

Thin, short rods, 0.5 by 1 to 3.0 microns. Motile (non-motile culture reported. See Starkey, Soil Sci., *39*, 1935, 197.) Gram-negative.

Thiosulfate medium (liquid): Pellicle consisting of cells and free sulfur.

Thiosulfate agar: Colonies small, circular, whitish yellow due to precipitated sulfur.

Optimum reaction: Close to neutrality.

Strictly autotrophic. Derives its energy by the oxidation of thiosulfate to sulfate and sulfur; also oxidizes sulfur to sulfate.

Aerobic.

Source: Sea water, river water, mud, sewage, and soil.

Habitat: Presumably widely distributed.

2. **Thiobacillus thiooxidans** Waksman and Joffe. (Jour. Bact., 7, 1922, 239; *Sulfomonas thiooxidans* Waksman, Jour. Bact., 7, 1922, 616; *Thiobacterium thiooxydans* Lehmann and Neumann, Bakt. Diag., 7 Aufl., *2*, 1927, 517.) From Greek *theion*, sulfur and M.L. to oxidize.

Short rods: 0.5 by 1.0 micron with rounded ends. Occur singly, in pairs, or in chains. Motile by means of a single polar flagellum. Gram-negative (Starkey, Soil Sci., *39*, 1935, 210).

Thiosulfate agar: Scant growth. Nearly transparent colonies.

Sulfur medium (liquid): Uniform turbidity. No sediment or surface growth. Medium becomes very acid (below pH 1.0).

Thiosulfate medium (liquid): Uniform turbidity. Medium becomes acid and sulfur is precipitated.

Nitrogen sources: Utilizes ammonia nitrogen but not nitrate nitrogen which is toxic. Asparagin, urea and peptone not utilized.

Temperature relations: Optimum 28° to 30°C. Slow growth at 18° and 37°C. Death occurs at 55° to 60°C.

Optimum reaction: pH 2.0–3.5. (Limiting reactions, pH 6.0 to less than pH 0.5.)

Strictly autotrophic, deriving its energy from the oxidation of elementary sulfur and thiosulfate, oxidizing these to sulfuric acid. It utilizes the CO_2 of the atmosphere as a source of carbon.

Strictly aerobic.

Distinctive characters: This species produces more acid, from oxidation of sulfur, and continues to live in a more acid medium, than any other living organism yet reported, the hydrogen-ion concentration of the medium increasing to a pH 0.6 and less.

Source: Isolated from composts of soil, sulfur, and rock phosphate and soils containing incompletely oxidized sulfur compounds.

Habitat: Soil.

3. **Thiobacillus novellus** Starkey. (Jour. Bact., *28*, 1934, 365; Jour. Gen. Physiol., *18*, 1935, 325; Soil Sci., *39*, 1935, 207, 210.) From Latin *novellus*, new.

Short rods or ellipsoidal cells: 0.4 to 0.8 by 0.6 to 1.8 microns. Non-motile. Gram-negative.

Gelatin stab: Mucoid growth at point of inoculation. Sub-surface growth meager. Slow liquefaction.

Agar plate: Growth slow, colorless, moist, raised, circular, 1 mm in diameter. Deep colonies tiny, lens-shaped.

Thiosulfate agar plate: Growth slow, becoming white from precipitated sulfur. Surface colonies small, circular, moist. Crystals of $CaSO_4$ appear throughout the agar.

Agar slant: Growth fairly abundant, soft, somewhat ropy, raised, shining, moderately spreading; whitish in reflected light, brownish opalescence in transmitted light.

Thiosulfate agar slant: Growth very thin, practically colorless. No sub-surface growth. Sulfur usually precipitated as white frosty film on the surface.

Agar stab: White to cream-colored growth confined close to point of inoculation. Penetrates to bottom of tube.

Thiosulfate agar stab: No appreciable surface growth.

Broth: Slightly turbid. Gelatinous pellicle. Forms long streamer-like network extending from surface to the bottom. Some sediment.

Thiosulfate solution medium: Uniform turbidity. No pellicle. Whitish sediment with thin incomplete membrane on the bottom of the flask. Reaction acid in a few days, changes pH 7.8 to 5.8 with decomposition of a small quantity of thiosulfate.

Sulfur solution medium of slightly alkaline reaction: No growth.

Potato slant: Growth limited, cream-colored, moist, shining, slightly brown.

Litmus milk: Slow development of slight alkalinity.

Facultative autotrophic.

Optimum reaction: Close to neutrality (limiting reactions pH 5.0 to 9.0).

Aerobic.

Distinctive characters: Oxidizes thiosulfate to sulfate and sulfuric acid. Does not oxidize free sulfur.

Source: Isolated from soils.

Habitat: Soils.

4. **Thiobacillus coproliticus** Lipman and McLees. (Soil Sci., *50*, 1940, 432.) Latinized form of the English word *coprolite*, fossil dung.

Long thin rods: 0.1 to 0.2 by 6 to 8 (may measure 3 to 40) microns. Straight, S-shaped, and curved cells. Motile by means of a single polar flagellum.

Peptone soil extract agar: Slight growth.

Nutrient solution: Little or no growth.

Thiosulfate agar: Slow development. Produces small watery colonies raised above the agar surface. Colonies have been noted which were white from precipitated sulfur.

Thiosulfate solution: Thiosulfate is oxidized. Little or no turbidity. No pellicle. No sediment. Change in reaction from pH 7.6 to 6.1.

Sulfur medium: Sulfur is oxidized. No turbidity.

Facultative autotrophic.

Aerobic.

Distinctive characters: Develops in inorganic media and oxidizes thiosulfate and sulfur to sulfate. Media with slightly alkaline reactions most favorable for growth.

Source: Coprolite rock material from Triassic period (Arizona).

Habitat: Unknown.

5. **Thiobacillus denitrificans** Beijerinck. (Cent. f. Bakt., II Abt., *11*, 1904, 597; *Sulfomonas denitrificans* Orla-Jensen, Cent. f. Bakt., II Abt., *22*, 1909, 314.) From Latin, *de*, from; and M.L. *nitrifico*, to nitrify.

Short rods, 0.5 by 1 to 3.0 microns long. Motile by means of a single polar flagel-

lum (Tjulpanova-Mossevitch, Arch. d. Sci. Biol., U.S.S.R., *30*, 1930, 203).

Inorganic liquid medium: Growth with production of gas, predominantly nitrogen.

Thiosulfate agar medium: Colonies thin, clear, or weakly opalescent.

Optimum reaction: Neutral or slightly alkaline.

Autotrophic, utilizing carbon from CO_2, carbonates and bicarbonates. Considered to be strictly autotrophic by Lieske (Ber. d. deutsch. botan. Gesell., *30*, 1912, 12.) and facultative by Tjulpanova-Mossevitch (*loc. cit.*). Beijerinck stated (Kon. Akad. v. Wetenschappen Amsterdam, *42*, 1920, 899) that whereas the organism developed initially in an inorganic medium, it lost the autotrophic habit by cultivation in an organic medium.

Facultative anaerobic or even microaerophilic. Can live in the absence of free O_2 in the presence of nitrate.

Distinctive characters: Oxidizes thiosulfate to sulfate under anaerobic conditions using nitrate as the hydrogen acceptor which is reduced to N_2. Also oxidizes sulfide, elemental sulfur, and dithionate.

Habitat: Canal and river water, salt water, soil, peat, composts and mud.

Appendix: The following species have been placed in *Thiobacillus* or are regarded as belonging to the genus:

Thiobacillus concretivorus Parker. (Austral. Jour. Exper. Biol. and Med. Sci., *23*, 1945, 81.) From corroded concrete sewers. Similar to or identical with *Thiobacillus thiooxidans* Waksman and Joffe.

Thiobacillus crenatus Emoto. (Proc. Imp. Acad. Tokyo, *5*, 1929, 149.) Isolated from mud of hot springs in Japan. See description, Manual, 5th ed., 1939, 84. Almost identical with *Thiobacillus thiooxidans* Waksman and Joffe.

Thiobacillus lobatus Emoto (*loc. cit.*, p. 148). Source and relationships as above. See description, Manual, 5th ed., 1939, 83.

Thiobacillus thermitanus Emoto. (Bot. Mag. Tokyo, *42*, 1928, 422.) Source and relationships as above. See description, Manual, 5th ed., 1939, 83.

Thiobacillus trautweinii Bergey et al. See *Flavobacterium* appendix.

Thiobacillus umbonatus Emoto (*loc. cit.*, p. 150). Source and relationships as above. See description, Manual, 5th ed., 1939, 84.

Thiobacterium beijerinckii Issatchenko and Salimowskaja. (Zur Morphologie u. Physiol. der Thionsäurebakterien (Russian with German abstract), Izyiestia Gosud. Gidrobiol. Inst., No. 21, 1928, 61.) From salt seas in Russia. Similar to or identical with *Thiobacillus thioparus* Beijerinck.

Thiobacterium beijerinckii var. *jacobsenii* Issatschenko and Salimowskaja (*loc. cit.*). Variety of previously mentioned species.

Thiobacterium nathansonii Issatchenko and Salimowskaja (*loc. cit.*). From salt seas in Russia. Similar to or identical with *Thiobacillus thioparus* Beijerinck.

FAMILY II. PSEUDOMONADACEAE WINSLOW ET AL.

(Jour. Bact., *2*, 1917, 555.)

Cells without endospores, elongate rods, straight or more or less spirally curved. One genus (*Mycoplana*) has branched cells. Usually motile by polar flagella which are either single or in small or large tufts. A few species are non-motile. Gram-negative (a few doubtful Gram-positive tests are recorded in *Pseudomonas*). Grow well and fairly rapidly on the surface of ordinary culture media excepting *Methanomonas* and some vibrios that attack cellulose. They are preferably aerobic, only certain vibrios including *Desulfovibrio* being anaerobic. Either water or soil forms, or plant or animal pathogens.

Key to the tribes of family **Pseudomonadaceae.**

1. Straight rods.
   Tribe I. *Pseudomonadeae*, p. 82.
2. Cells more or less spirally curved.
   Tribe II. *Spirilleae*, p. 192.

TRIBE I. PSEUDOMONADEAE KLUYVER AND VAN NIEL.

(Cent. f. Bakt., II Abt., *94*, 1936, 397.)

This tribe includes all of the straight and branching rods of the family.

Key to the genera of tribe **Pseudomonadeae.**

I. Soil and water bacteria. Few animal and many plant pathogens. Usually produce a water-soluble pigment which diffuses through the medium as a bluish-green or yellowish-green pigment.
   Genus I. *Pseudomonas*, p. 82.

II. Cells usually monotrichous with yellow non-water-soluble pigment. Mostly plant pathogens causing necrosis.
   Genus II. *Xanthomonas*, p. 150.

III. Soil bacteria which oxidize methane.
   Genus III. *Methanomonas*, p. 179.

IV. Bacteria which oxidize alcohol to acetic acid.
   Genus IV. *Acetobacter*, p. 179.

V. Soil and water bacteria known to attack protamines.
   Genus V. *Protaminobacter*, p. 189.

VI. Soil bacteria with branching cells. Capable of using aromatic compounds, as phenol, etc., as a source of energy.
   Genus VI. *Mycoplana*, p. 191.

Genus I. **Pseudomonas** *Migula.**

(Migula Arb. bakt. Inst. Karlsruhe, *1*, 1894, 237; *Bacterium* Ehrenberg *emend.* Cohn, Beitr. z. Biol. d. Pflanzen, *1*, Heft 1, 1872, 167; *Bactrillum* Fischer, Jahrb. f. wissensch. Bot., *27*, 1895, 139; *Bactrinium* Fischer, *ibid.*, 41; *Arthrobactrinium* Fischer, *ibid.*, 139; *Arthrobactrillum* Fischer, *ibid.*, 139; *Bactrinius* Kendall, Public Health, *28*, 1902, 484; *Bactrillius* Kendall, *ibid.*; *Bacterium* Ehrenberg *emend.* Smith, Bacteria

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* Revised for the 5th ed. of the Manual by Prof. D. H. Bergey, Philadelphia, Pennsylvania, 1937. Further revision for the 6th ed. by Prof. R. S. Breed, New York State Experiment Station, Geneva, New York, with incorporation of the plant pathogenic species by Prof. Walter H. Burkholder, Cornell University, Ithaca, New York. April, 1943.

in Relation to Plant Disease, *1*, 1905, 171; *Denitromonas* Orla-Jensen, Cent. f. Bakt., II Abt., *22*, 1909, 314; *Liquidomonas* Orla-Jensen, *ibid.*, 332; *Lamprella* Enderlein, Sitzber. Gesell. naturf. Freunde, Berlin, 1917, 317; *Fluoromonas* Orla-Jensen, Jour. Bact., *6*, 1921, 271.)

Cells monotrichous, lophotrichous or non-motile. If pigments are produced, they are of greenish hue, fluorescent, and water-soluble.* Gram-negative except Nos. 88, 122 and 128. Frequently ferment glucose, sometimes with the formation of visible gas. Inactive in the fermentation of lactose. Nitrates are frequently reduced either to nitrites or ammonia, or to free nitrogen. Some species split fat and attack hydrocarbons. Soil, water, and plant pathogens; very few animal pathogens. Certain salt water species (Nos. 58–64) some of which live in heavy brine are temporarily retained in this genus although they produce non-water-soluble pigments or phosphorescence. From Gr. *pseudes*, false; *monas*, a unit; M. L. monad.

The type species is *Pseudomonas aeruginosa* (Schroeter) Migula.

Key to the species of genus Pseudomonas.

I. Soil and fresh water forms with a few that are pathogenic on cold or warm blooded animals.
- 1. Green fluorescent pigment produced.
  - a. Gelatin liquefied.
    - b. Polar flagellate.
      - c. Grow readily at 37°C. Usually bluish-green.
        - 1. *Pseudomonas aeruginosa.*
        - 2. *Pseudomonas jaegeri.*
      - cc. Grow poorly or not at all at 37°C.
        - d. Milk not coagulated becoming alkaline.
          - e. Soil and water organisms. Not known to digest cellulose.
            - 3. *Pseudomonas fluorescens.*
            - 4. *Pseudomonas viscosa.*
            - 5. *Pseudomonas fairmountensis.*
            - 6. *Pseudomonas ureae.*
            - 7. *Pseudomonas pavonacea.*
          - ee. Soil forms that attack cellulose.
            - 8. *Pseudomonas effusa.*
          - eee. Pathogenic for lizards.
            - 9. *Pseudomonas reptilivorous.*
        - dd. Milk unchanged becoming blue in association with lactic acid bacteria.
          - 10. *Pseudomonas syncyanea.*
        - ddd. Milk coagulated.
          - 11. *Pseudomonas schuylkilliensis.*
          - 12. *Pseudomonas chlororaphis.*
          - 13. *Pseudomonas myxogenes.*
          - 14. *Pseudomonas septica.*
        - dddd. Soil form. Action on milk not recorded.
          - 15. *Pseudomonas boreopolis.*

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* See Tobie, Jour. Boct., *49*, 1945, 459 for a discussion of the natụre of these pigments.

bb. Non-motile.
c. Grows readily at 37°C.
16. *Pseudomonas smaragdina.*
cc. Grows poorly or not at all at 37°C.
17. *Pseudomonas chlorina.*
aa. Gelatin not liquefied.
b. Polar flagellate.
c. Grow readily at 37°C. Usually bluish-green.
18. *Pseudomonas oleovorans.*
19. *Pseudomonas incognita.*
20. *Pseudomonas convexa.*
21. *Pseudomonas mildenbergii.*
cc. Grow poorly or not at all at 37°C.
d. Milk not coagulated.
22. *Pseudomonas putida.*
23. *Pseudomonas scissa.*
24. *Pseudomonas ovalis.*
25. *Pseudomonas striata.*
26. *Pseudomonas denitrificans.*
dd. Milk coagulated.
27. *Pseudomonas solaniolens.*
bb. Non-motile.
c. Grows poorly or not at all at 37° C.
d. Milk not coagulated.
28. *Pseudomonas eisenbergii.*
2. Green fluorescent pigment not produced or not reported.
a. Gelatin liquefied.
b. Polar flagellate.
c. Grow poorly or not at all at 37°C. No visible gas from sugars.
d. Rapid reduction litmus. Putrid odor.
29. *Pseudomonas putrefaciens.*
dd. Slow reduction litmus. Alkaline.
30. *Pseudomonas mephitica.*
31. *Pseudomonas geniculata.*
ddd. Acid coagulated.
32. *Pseudomonas fragi.*
cc. Acid and visible gas from glucose. Optimum temperature variable.
d. Litmus milk reduced and alkaline.
33. *Pseudomonas nebulosa.*
dd. Litmus milk acid coagulated.
34. *Pseudomonas coadunata.*
35. *Pseudomonas multistriata.*
36. *Pseudomonas punctata.*
37. *Pseudomonas hydrophila.*
38. *Pseudomonas ichthyosmia.*
aa. Gelatin not liquefied.
b. Polar flagellate.
c. Grow at 37°C.

39. *Pseudomonas ambigua.*
40. *Pseudomonas sinuosa.*
41. *Pseudomonas cruciviae.*

cc. Grow poorly or not at all at 37°C.
d. Action on hydrocarbons and cellulose unknown.
42. *Pseudomonas rugosa.*
dd. Utilize hydrocarbons.
43. *Pseudomonas desmolyticum.*
44. *Pseudomonas rathonis.*
45. *Pseudomonas dacunhae.*
46. *Pseudomonas arvilla.*
47. *Pseudomonas salopium.*
ddd. Utilize cellulose.
48. *Pseudomonas minuscula.*
49. *Pseudomonas tralucida.*
50. *Pseudomonas mira.*

aaa. Action on gelatin not recorded. Produces alcoholic fermentation of glucose.
51. *Pseudomonas lindneri.*

II. Sea water to brine species. Some species phosphorescent.
a. Gelatin liquefied.
b. Polar flagellate.
c. From sea water. Not deeply pigmented.
d. Nitrites not produced from nitrates.
52. *Pseudomonas membranoformis.*
53. *Pseudomonas marinoglutinosa.*
dd. Nitrites produced from nitrates so far as known.
e. Digest agar.
54. *Pseudomonas gelatica.*
ee. Deposit calcium carbonate in sea water gelatin and agar media in old cultures.
55. *Pseudomonas calcis.*
56. *Pseudomonas calciprecipitans.*
eee. Causes skin lesions in marine fish.
57. *Pseudomonas ichthyodermis.*
cc. Produce highly colored pigments in media containing salt or in heavy brines.
d. Blackens salted butter.
58. *Pseudomonas nigrificans.*
dd. Causes purple discoloration of salted beans.
59. *Pseudomonas beijerinckii.*
ddd. Reddens heavy brines (more than 18 per cent salt).
60. *Pseudomonas salinaria.*
61. *Pseudomonas cutirubra.*
ccc. Phosphorescent bacteria from decaying fish and crustaceans, and phosphorescent organs of sea animals.
d. Gelatin liquefied.
62. *Pseudomonas harveyi.*
dd. Gelatin not liquefied.
63. *Pseudomonas phosphorescens.*
64. *Pseudomonas pierantonii.*

III. Plant pathogens, causing leaf spot, leaf stripe and similar diseases.
- 1. Green fluorescent pigment produced.
  - a. Gelatin liquefied.
    - b. Acid from sucrose.
      - c. Nitrites produced from nitrates.
        - 65. *Pseudomonas martyniae.*
        - 66. *Pseudomonas striafaciens.*
        - 67. *Pseudomonas tomato.*
      - cc. Nitrites not produced from nitrates.
        - d. Growth in 5 per cent salt.
          - 68. *Pseudomonas aceris.*
          - 69. *Pseudomonas angulata.*
          - 70. *Pseudomonas aptata.*
          - 71. *Pseudomonas primulae.*
          - 72. *Pseudomonas viridilivida.*
        - dd. No growth in 5 per cent salt.
          - e. Beef peptone agar turns brown.
            - 73. *Pseudomonas delphinii.*
          - ee. Beef peptone agar uncolored.
            - 74. *Pseudomonas berberidis.*
            - 75. *Pseudomonas coronafaciens.*
            - 75a. *Pseudomonas coronafaciens* var. *atropupurea.*
            - 76. *Pseudomonas lachrymans.*
            - 77. *Pseudomonas maculicola.*
            - 78. *Pseudomonas marginata.*
            - 79. *Pseudomonas medicaginis.*
            - 79a. *Pseudomonas phaseolicola.*
            - 80. *Pseudomonas pisi.*
            - 81. *Pseudomonas syringae.*
        - ddd. Growth in salt solutions not recorded.
          - 82. *Pseudomonas atrofaciens.*
          - 83. *Pseudomonas cumini.*
          - 84. *Pseudomonas desaiana.*
          - 85. *Pseudomonas erodii.*
          - 86. *Pseudomonas apii.*
          - 87. *Pseudomonas matthiolae.*
          - 88. *Pseudomonas mors-prunorum.*
          - 89. *Pseudomonas rimaefaciens.*
          - 90. *Pseudomonas papulans.*
          - 91. *Pseudomonas pseudozoogloeae.*
          - 92. *Pseudomonas tabaci.*
      - ccc. Nitrite production not reported.
        - 93. *Pseudomonas lapsa.*
    - bb. No acid from sucrose.
      - c. Nitrites produced from nitrates.
        - 94. *Pseudomonas bowlesiae.*
        - 95. *Pseudomonas intybi.*
        - 96. *Pseudomonas marginalis.*
        - 97. *Pseudomonas setariae.*

cc. Nitrites not produced from nitrates.
d. Lipolytic.
98. *Pseudomonas polycolor.*
dd. Not lipolytic.
99. *Pseudomonas viridiflava.*
99a. *Pseudomonas viridiflava* var. *concentrica.*
ddd. Lipolytic action not reported.
100. *Pseudomonas ananas.*
101. *Pseudomonas ligustri.*
102. *Pseudomonas sesami.*
103. *Pseudomonas tolaasii.*
bbb. Acid from sucrose not reported.
c. Nitrites produced from nitrates.
d. Motile.
104. *Pseudomonas xanthochlora.*
dd. Non-motile.
105. *Pseudomonas rhizoctonia.*
cc. Nitrites not produced from nitrates.
106. *Pseudomonas barkeri.*
107. *Pseudomonas gladioli.*
108. *Pseudomonas mellea.*
ccc. Nitrite production not reported.
109. *Pseudomonas betlis.*
110. *Pseudomonas panacis.*
a. Gelatin not liquefied.
b. Acid from sucrose.
c. Nitrites produced from nitrates.
111. *Pseudomonas aleuritidis.*
cc. Nitrites not produced from nitrates.
112. *Pseudomonas glycinea.*
112a. *Pseudomonas glycinea* var. *japonica.*
113. *Pseudomonas savastanoi.*
113a. *Pseudomonas savastanoi* var. *fraxini.*
114. *Pseudomonas tonelliana.*
bb. No acid from sucrose.
c. Nitrites not produced from nitrates.
115. *Pseudomonas calendulae.*
116. *Pseudomonas cichorii.*
117. *Pseudomonas cissicola.*
118. *Pseudomonas nectarophila.*
119. *Pseudomonas viburni.*
bbb. Acid from sucrose not reported.
c. Nitrites not produced from nitrates.
120. *Pseudomonas mori.*
121. *Pseudomonas stizolobii.*
122. *Pseudomonas viciae.*
2. Green fluorescent pigment not produced or not reported.
a. Gelatin liquefied.
b. Acid from sucrose.

c. Nitrites produced from nitrates.
d. Beef-peptone agar turns dark brown.
123. *Pseudomonas alliicola.*
124. *Pseudomonas gardeniae.*
dd. Beef-peptone agar remains uncolored or light discoloration after several weeks.
e. Colonies tan to brown.
125. *Pseudomonas caryophylli.*
126. *Pseudomonas solanacearum.*
126a. *Pseudomonas solanacearum* var. *asiatica.*
ee. Colonies white or colorless.
127. *Pseudomonas castaneae.*
128. *Pseudomonas seminum.*
cc. Nitrites not produced from nitrates.
129. *Pseudomonas passifloriae.*
bb. No acid from sucrose.
130. *Pseudomonas fabae.*
bbb. Acid from sucrose not reported.
c. Nitrites not produced from nitrates.
131. *Pseudomonas astragali.*
132. *Pseudomonas colurnae.*
133. *Pseudomonas maublancii.*
134. *Pseudomonas polygoni.*
cc. Nitrate production not reported.
135. *Pseudomonas iridicola.*
136. *Pseudomonas levistici.*
137. *Pseudomonas radiciperda.*
aa. Gelatin not liquefied.
b. Acid from sucrose.
c. Nitrites not produced from nitrates.
138. *Pseudomonas melaphthora.*
cc. Gas from nitrates.
139. *Pseudomonas helianthi.*
bb. No acid from sucrose.
c. Nitrites produced from nitrates.
140. *Pseudomonas alboprecipitans.*
141. *Pseudomonas petasitis.*
142. *Pseudomonas lignicola.*
cc. Nitrites not produced from nitrates.
143. *Pseudomonas andropogoni.*
144. *Pseudomonas woodsii.*
bbb. Acid from sucrose not reported.
c. Nitrites produced from nitrates.
145. *Pseudomonas panici-miliacei.*
146. *Pseudomonas saliciperda.*
cc. Nitrites not produced from nitrates.
147. *Pseudomonas eriobotryae.*
aaa. Gelatin liquefaction not reported.
b. Nitrites not produced from nitrates.
148. *Pseudomonas wieringae.*

1. **Pseudomonas aeruginosa** (Schroeter) Migula. (*Bacterium aeruginosum* Schroeter, in Cohn, Beitrage z. Biologie, *1*, Heft 2, 1872, 126; *Bacillus pyocyaneus* Gessard, Compt. rend. Acad. Sci., Paris, *94*, 1882, 536; *Micrococcus pyocyaneus* Zopf, Spaltpilze, 2 Aufl., 1884, 83; *Bacillua aeruginosus* Trevisan, Atti Accad. Fis.-Med. Stat., Milano, Ser. 4, *3*, 1885, 11; *Bacillus fluorescens* Crookshank, Man. of Bact., 3rd ed., 1890, 247; not *Bacillus fluorescens* Bergey et al., Manual, 1st ed., 1923, 287; *Pseudomonas pyocyanea* Migula, in Engler and Prantl, Die natürl. Pflanzenfam, *1*, 1a, 1895, 29; *Bacterium pyocyaneum* Lehmann and Neumann, Bakt. Diag., 1 Aufl., *2*, 1896, 267; Migula, Syst. Bakt., *2*, 1900, 884.) From Latin, full of copper rust, or verdigris; green.

Rods: 0.5 to 0.6 by 1.5 microns, occurring singly, in pairs and short chains. Motile, possessing one to three polar flagella. Monotrichous (Reid, Naghski, Farrell and Haley, Penn. Agr. Exp. Sta., Bull. 422, 1942, 6). Gram-negative.

Gelatin colonies: Yellowish or greenish-yellow, fringed, irregular, skein-like, granular, rapidly liquefying.

Gelatin stab: Rapid liquefaction. The fluid assumes a yellowish-green or bluish-green color.

Agar colonies: Large, spreading, grayish with dark center and translucent edge, irregular. Medium greenish.

Agar slant: Abundant, thin, white, glistening, the medium turning green to dark brown or black, fluorescent.

Broth: Marked turbidity with thick pellicle and heavy sediment. Medium yellowish-green to blue, with fluorescence, later brownish. Produces pyocyanin, fluorescein and pyrorubrin (Am. Jour. Hyg., *5*, 1925, 707).

Litmus milk: A soft coagulum is formed, with rapid peptonization and reduction of litmus. Reaction alkaline.

Potato: Luxuriant, dirty-brown, the medium becoming dark green.

Indole usually not formed (Sandiford, Jour. Path. and Bact., *44*, 1937, 567).

Nitrates are reduced to nitrites and nitrogen.

Glucose, fructose, galactose, arabinose, maltose, lactose, sucrose, dextrin, inulin, glycerol, mannitol and dulcitol are not attacked. Acid from glucose (Sandiford, *loc. cit.*).

Blood serum: Liquefied. Yellow liquid, greenish on surface.

Blood hemolyzed.

Cultures have marked odor of trimethylamine.

Aerobic, facultative.

Optimum temperature 37°C.

Pathogenic for rabbits, guinea pigs, rats and mice.

Common name: Blue pus organism.

Source: Pus from wounds. Regarded as identical with one of the plant pathogens (*Pseudomonas polycolor*) by Elrod and Braun (Jour. Bact., *44*, 1942, 633).

Habitat: Cause of various human and animal lesions. Found in polluted water and sewage.

2. **Pseudomonas jaegeri** Migula. (*Bacillus proteus fluorescens* H. Jaeger, Ztschr. f. Hyg., *12*, 1892, 593; Migula, Syst. d. Bakt., *2*, 1900, 885; *Bacillus proteus-fluorescens* Holland, Jour. Bact., *5*, 1920, 220; *Proteus fluorescens* Holland, *ibid.*, 224; *Pseudomonas protea-fluorescens* Holland, *ibid.*, 224.) Named for H. Jaeger who first described the species.

Short, thick rods, with rounded ends, occurring singly and in pairs. Motile with a tuft of polar flagella which may be pushed to one side where cells remain in a chain. Gram-negative.

Gelatin colonies: Small, transparent, becoming proteus-like.

Gelatin stab: Marked surface growth. Saccate to infundibuliform liquefaction. Liquefied portion green fluorescent.

Agar slant: Thick, yellowish-white layer, the medium becoming greenish-fluorescent. At times gas is formed.

Broth: Turbid, with greenish-gray pellicle and sediment.

Litmus milk: Not coagulated.

Potato: Thick, pale yellow becoming dark brown layer, slimy. The medium becomes bluish-gray.

Indole not formed.

Nitrites not produced from nitrates.

Aerobic, facultative.

Optimum temperature 37°C.

Pathogenic for mice.

Source: Regarded by Jaeger as the cause of Weil's disease (infectious jaundice) as it was found repeatedly in patients suffering from this disease. See *Leptospira icterohaemorrhagiae*.

Habitat: Water.

3. **Pseudomonas fluorescens** Migula. (*Bacillus fluorescens liquefaciens* Flügge, Die Mikroorganismen, 1886, 289; Migula, in Engler and Prantl, Die natürl. Pflanzenfamilien, 1, 1a, 1895, 29; *Bacterium fluorescens* Lehmann and Neumann, Bakt. Diag., 1 Aufl., *2*, 1896, 272.) From Latin, *fluor*, flowing; M.L. *fluoresco*, to fluoresce.

Rods: 0.3 to 0.5 by 1.0 to 1.8 microns, occurring singly and in pairs. Motile, possessing a polar flagellum. Gram-negative.

Gelatin colonies: Circular, with greenish center, lobular, liquefying quickly.

Gelatin stab: Infundibuliform liquefaction, with whitish to reddish-gray sediment.

Agar slant: Abundant, reddish layer, becoming reddish-gray. The medium shows greenish to olive-brown coloration.

Broth: Turbid, flocculent, with yellowish-green pellicle and grayish sediment.

Litmus milk: No coagulation; becoming alkaline.

Potato: Thick, grayish-yellow, spreading, becoming light sepia-brown in color.

Indole is not formed.

Nitrates reduced to nitrites and ammonia.

Acid from glucose.

Blood serum liquefied.

Aerobic.

Optimum temperature 20° to 25°C.

Not pathogenic.

Source: Water, sewage, feces.

Habitat: Soil and water.

4. **Pseudomonas viscosa** (Frankland and Frankland) Migula. (*Bacillus viscosus* G. and P. Frankland, Ztschr. f. Hyg., *6*, 1889, 391; Migula, Syst. d. Bakt., *2*, 1900, 900.) From M. L. *viscidus*, sticky, viscid.

Small rods: 0.5 by 1.5 to 2.0 microns, occurring singly. Motile and presumably polar flagellate. Gram-negative.

Gelatin colonies: Grayish, granular, with fimbriate margin. Medium assumes a green fluorescent color around each colony.

Gelatin stab: Infundibuliform liquefaction. Liquefied portion green fluorescent with greenish-white pellicle.

Agar slant: Thin, greenish-white, the medium becoming greenish.

Broth: Turbid, with greenish pellicle.

Litmus milk: Not coagulated.

Potato: Moist, chocolate-brown, viscid.

Indole not formed.

Nitrites not produced from nitrates. Destroys nitrate with the production of ammonia.

Aerobic, facultative.

Distinctive characters: Resembles *Pseudomonas fluorescens* except that growth on agar, gelatin and potato is viscid.

Optimum temperature 20°C.

Source: Unfiltered water from Kent, England. Common.

Habitat: Water.

5. **Pseudomonas fairmountensis** (Wright) Chester. (*Bacillus fairmountensis* Wright, Memoirs Nat. Acad. Sci., *7*, 1895, 458; Chester, Man. Determ. Bact., 1901, 311; *Achromobacter fairmountense* Bergey et al., Manual, 1st ed., 1923, 146.) From M. L. of Fairmount Park (Philadelphia.)

Medium-sized rods, occurring singly, in pairs and in chains. Motile, possessing polar flagella. Gram-negative.

Gelatin colonies: Circular, white, translucent. Dark centers with a greenish shimmer, thinner edges and faint radial lines.

Gelatin stab: Crateriform liquefaction.

Agar slant: Grayish-white, glistening.
Broth: Turbid.
Litmus milk: Alkaline, litmus reduced.
Potato: Raised, granular, spreading, viscid.
Indole is formed.
Nitrites not produced from nitrates.
Aerobic, facultative.
Optimum temperature 20° to 25°C.
Habitat: Water.

6. **Pseudomonas ureae** Bergey et al. (Culture No. 3 of Rubentschick, Cent. f. Bakt., II Abt., *72*, 1927, 101; Bergey et al., Manual, 3rd ed., 1930, 173.) From Greek, *urum*, urine; M. L., *urea*, urea.

Rods: 0.6 to 0.7 by 1.7 to 2.0 microns, occurring singly and in pairs. Motile. Gram-positive.

Gelatin stab: Infundibuliform liquefaction.

Agar colonies: Circular, grayish-white.

Agar slant: Grayish-white layer becoming greenish-fluorescent.

Broth: Turbid.

Litmus milk: Peptonized.

Potato: Yellowish-brown streak.

Indole not formed.

Nitrates reduced with gas formation. Ammonia formed.

Urea attacked.

Hydrogen sulfide formed.

Methylene blue reduced.

Aerobic, facultative.

Can grow at 0° C.

Optimum temperature 20°C.

Habitat: Sewage filter beds.

This species is included here through an oversight. It should have been placed in the Appendix to the genus *Pseudomonas* as the original description is too incomplete to determine its real nature. It is reported to be Gram-positive and motile; but the number and arrangement of flagella are not given. If it really is Gram-positive, the species is probably peritrichous and does not belong in *Pseudomonas*.

7. **Pseudomonas pavonacea** Levine and Soppeland. (Bul. No. 77, Iowa State Agricultural College, 1926, 41.) From Latin, *pavo*, peacock.

Rods: 0.5 by 4.5 microns, with truncate ends, occurring singly and in chains. Motile. Gram-negative.

Gelatin stab: Crateriform liquefaction. Medium becoming brown.

Agar colonies: Circular, raised, becoming green, amorphous, entire.

Agar slant: Greenish, smooth, glistening, viscid, medium becoming slightly brown.

Broth: Turbid, with viscid sediment. Medium turned dark brown.

Litmus milk: Slightly alkaline. Litmus reduced. Peptonized after 10 days.

Potato: No growth.

Indole not formed.

Nitrites not produced from nitrates.

Starch not hydrolyzed.

Blood serum liquefied in 5 days.

No acid or gas from carbohydrate media.

Aerobic, facultative.

Optimum temperature 22°C.

Source: Isolated from activated sludge.

8. **Pseudomonas effusa** Kellerman et al. (Kellerman, McBeth, Scales and Smith, Cent. f. Bakt., II Abt., *39*, 1913, 515; also Soil Science, *1*, 1916, 472; *Cellulomonas effusa* Bergey et al., Manual, 1st ed., 1923, 162; *Bacillus effusus* appears first as a synonym in Bergey at al., *ibid.*; later used as name of species 5th ed., 1939, 616.) From Latin, *effusus*, effuse, spread out.

Rods: 0.4 by 1.7 microns. Motile with one to three polar flagella. Gram-negative.

Gelatin stab: Liquefaction.

Agar slant: Luxuriant, glistening, moist, creamy growth. Greenish fluorescence.

Peptone starch agar slant: Abundant, flat, moist rich creamy growth. Medium shows greenish fluorescence.

Broth: Turbid.

Litmus milk: Alkaline. Coagulation and digestion.

Potato: Rich, creamy spreading growth.

Indole not formed.

Nitrites not produced from nitrates.

Ammonia is produced.

Acid from glucose, maltose, starch, glycerol and mannitol. No acid from lactose or sucrose.

Cellulose is attacked.

Aerobic, facultative.

Optimum temperature 20°C.

Source: Isolated from soils in Utah.

Habitat: Soil.

8a. *Pseudomonas effusa* var. *non-liquefaciens* Kellerman et al. (*loc. cit.*). A non-liquefying variety that acts more slowly on litmus milk.

Source: Soils from Utah.

9. **Pseudomonas reptilivorous** Caldwell and Ryerson. (Jour. Bact., *39*, 1940, 335.) From Latin, *reptile*, a reptile and *voro*, to devour, destroy.

Rods: 0.5 by 1.5 and 2.0 microns, occurring singly, in pairs and in short chains and having rounded ends. Actively motile with two to six polar flagella. Gram-negative.

Gelatin colonies: After 24 hours, small, circular, smooth, entire. Liquefaction with a yellowish-green fluorescence.

Gelatin stab: Infundibuliform liquefaction becoming stratiform. Putrid odor present.

Agar cultures: Circular, smooth, glistening, slightly raised, butyrous, translucent, 2 mm in diameter.

Agar slant: Growth abundant, smooth, filiform, glistening, butyrous and translucent.

Broth: Turbid with pellicle and sediment. Putrid odor.

Litmus milk: Alkaline, peptonization, complete reduction. Disagreeable odor.

Potato: Growth moderate, spreading, glistening, yellowish-gray to creamy. Disagreeable odor. Medium becomes brownish-gray.

Indole not formed.

Nitrates not produced from nitrates.

Hydrogen sulfide not produced.

Slightly acid, becoming alkaline in glucose. No acid from arabinose, xylose, lactose, sucrose, maltose, trehalose, raffinose, mannitol, dulcitol, inositol and salicin.

Starch not hydrolyzed.

Pathogenic for guinea pigs and rabbits, horned lizards, Gila monsters and chuckwallas.

Temperature relations: Optimum 20° to 25°C. Maximum 37°C.

Distinctive characters: Yellowish-green fluorescence present in meat infusion media. Pathogenic.

Source: Isolated in a bacterial disease of horned lizards and Gila monsters.

Habitat: Pathogenic for lizards.

10. **Pseudomonas syncyanea** (Ehrenberg) Migula. (*Vibrio syncyaneus* Ehrenberg, Berichte ü.d. Verh. d. k. Preuss. Akad. d. Wissensch. z. Berlin, *5*, 1840, 202; *Vibrio cyanogenes* Fuchs, Magazin für die gesamte Tierheilkunde, *7*, 1841, 190; *Bacillus syncyaneus* Schroeter, Kryptogam. Flora von Schlesien, *3*, 1, 1886, 157; *Bacillus cyanogenus* Zopf, Die Spaltpilze, 3 Aufl., 1885, 86; Migula, in Engler and Prantl, Die natürl. Pflanzenfam., *1*, 1a, 1895, 29; *Bacterium syncyaneum* Lehmann and Neumann, Bakt. Diag., 1 Aufl., *2*, 1896, 275; *Pseudomonas cyanogenes* Holland, Jour. Bact., *5*, 1920, 224.) From Greek, *syn*, with; *kyaneos*, dark blue, dark.

Rods with rounded ends, occurring singly, occasionally in chains, 0.7 by 2.0 to 4.0 microns. Motile with two to four polar flagella. Gram-negative.

Gelatin colonies: Flat, bluish, translucent.

Gelatin stab: Surface growth shiny, grayish blue. The medium is colored steel-blue with greenish fluorescence. Gelatin is liquefied. Some strains do not liquefy.

Agar slant: Grayish-white streak. The medium takes on a bluish-gray color with slight fluorescence.

Broth: Turbid with marked fluorescence.

Litmus milk: Unchanged. In association with lactic acid bacteria the milk takes on a deep blue color.

Potato: Yellowish-gray, shiny layer, becoming bluish-gray. The medium becomes bluish-gray.

Indole not formed.

Nitrites not produced from nitrates.

Aerobic, facultative.

Optimum temperature 25°C.

Habitat: The cause of blue milk.

11. **Pseudomonas schuylkilliensis** Chester. (*Bacillus fluorescens schuylkilliensis* Wright, Memoirs, Natl. Acad. Sci., *7*, 1895, 448; Chester, Determinative Bact., 1901, 320.) From M. L. of the Schuylkill (River).

Synonyms: *Pseudomonas capsulata* Chester, Man. Determ. Bact., 1901, 322 (*Bacillus fluorescens capsulatus* Pottien, Ztschr. f. Hyg., *11*, 1896, 140); *Pseudomonas dermatogenes* Fuhrmann, Cent. f. Bakt., II Abt., *17*, 1906, 356.

Short rods, with rounded ends, occurring singly, in pairs and in chains. Motile, possessing a polar flagellum. Gram-negative.

Gelatin colonies: Grayish-white, translucent, with brownish center, radiate margin, becoming bluish-green.

Gelatin stab: Slow crateriform liquefaction, with blue-green fluorescence.

Agar slant: Grayish, translucent growth. Medium shows greenish fluorescent.

Broth: Turbid, with slight pellicle and blue-green fluorescence. Stringy sediment.

Litmus milk: Coagulated, with slow reduction of litmus; peptonized.

Potato: Brownish, spreading, viscid, thick.

Indole is formed (trace).

Nitrites not produced from nitrates.

Aerobic, facultative.

Does not grow at 35° to 36°C.

Source: Isolated from Schuylkill River water.

Habitat: Water.

12. **Pseudomonas chlororaphis** (Guignard and Sauvageau) Bergey et al. (*Bacillus chlororaphis* Guignard and Sauvageau, Compt. rend. Soc. Biol. Paris, *1*, 10 sér., 1894, 841; Bergey et al., Manual, 3d ed., 1930, 166; also see Lasseur and Dupaix-Lasseur, Trav. Lab. Microbiol. Fac. Pharm. Nancy, Fasc. 9, 1936, 35.) From Greek, *chlōros*, greenish yellow; *raphis*, needle.

Rods: 0.8 by 1.5 microns, with rounded ends, occurring singly and in pairs. Motile with polar flagella. Gram-negative.

Gelatin colonies: Circular, viscid, transparent, glistening, lobate margin, with fluorescent corona. Dissociates readily (Lasseur and Dupaix-Lasseur, *loc. cit.*).

Gelatin stab: Stratiform liquefaction.

Broth: Turbid, fluorescent, with crystals of green, water-soluble chlororaphine.

Litmus milk: Coagulation. Peptonization. Crystals of chlororaphine form in the central part of the culture.

Potato: Citron-yellow layer. Crystals of chlororaphine are formed.

Nitrates reduced to nitrites.

Indole not formed.

Pigment formation: Asparagine, potassium phosphate, glycerol, sulfate of magnesium and sulfate of iron are indispensable to the formation of crystals of chlororaphine.

Aerobic, facultative. Optimum temperature 25° to 30°C.

Pathogenic for laboratory animals. Exotoxin formed.

Habitat: Water.

13. **Pseudomonas myxogenes** Fuhrmann. (Cent. f. Bakt., II Abt., *17*, 1907, 356.) From Greek, *myxa*, mucus; *gennaō*, to beget; M. L. slime producing.

Rods: 0.4 to 0.5 by 1.0 to 1.5 microns, occurring singly and in pairs. Motile, possessing a bundle of five to seven polar flagella. Gram-negative.

Gelatin colonies: Smooth, soft, flat, spreading, entire, yellowish-green.

Gelatin stab: Growth along stab. Liquefaction with yellowish-white sediment.

Agar colonies: Circular, raised, smooth, amorphous, entire.

Agar slant: Yellowish-white, moist, glistening, becoming light green-fluorescent.

Broth: Turbid, with yellowish-white sediment.

Litmus milk: Flocculent precipitation. Slow peptonization with yellow serum. Alkaline.

Potato: Dirty yellow to olive, moist, glistening, entire.

Indole is formed.

Nitrates reduced to nitrites and ammonia. No gas formed.

Aerobic, facultative.

Optimum temperature 22°C.

Source: Isolated from beer.

14. **Pseudomonas septica** Bergey et al. (*Bacillus fluorescens septicus* Stutzer and Wsorow, Cent. f. Bakt., II Abt., *71*, 1927, 113; Bergey et al., Manual, 3rd ed., 1930, 169.) From Greek, *septikos*, putrefactive, septic.

Rods: 0.6 to 0.8 by 0.8 to 2.0 microns, occurring singly. Motile with a polar flagellum. Gram-negative.

Gelatin stab: Infundibuliform liquefaction.

Agar colonies: Circular with opalescent center and transparent periphery.

Agar slant: Moderate, undulate margin.

Broth: Turbid with fragile pellicle, greenish in upper portion.

Litmus milk: Alkaline, coagulated.

Blood serum not liquefied.

Acid from glucose.

Aerobic, facultative.

Optimum temperature 20°C.

Habitat: Disease of caterpillars.

15. **Pseudomonas boreopolis** Gray and Thornton. (Gray and Thornton, Cent. f. Bakt., II Abt., *73*, 1928, 74.) From Greek, *boreas*, the North wind; *polis*, city; M. L. North City.

Rods: 0.5 to 1.0 by 2.0 to 3.0 microns, occurring singly and in pairs. Motile with one to five polar flagella. Gram-negative.

Gelatin colonies: Liquefied.

Gelatin stab: Liquefied. Medium reddened.

Agar colonies: Circular or amoeboid, white to buff, flat to convex, smooth, glistening, translucent border.

Agar slant: Filiform, whitish, raised, smooth, glistening, fluorescent.

Broth: Turbid.

Nitrates reduced to nitrites.

Starch not hydrolyzed.

Acid produced from glucose.

Attacks naphthalene.

Aerobic, facultative.

Optimum temperature 20° to 25°C.

Habitat: Soil.

16. **Pseudomonas smaragdina** Migula. (*Bacillus smaragdinus foetidus* Reiman, Inaug. Dissertation, Würzburg, 1887; Migula, Syst. d. Bakt., *2*, 1900, 890.) From Greek, *smaragdinas*, green like the *smaragdus*, the emerald.

Small rods, occurring singly. Nonmotile. Gram-negative.

Gelatin colonies: Small, convex, irregular, whitish with greenish shimmer.

Gelatin stab: Slight surface growth. Infundibuliform liquefaction. The liquefied medium becomes light emerald green in color.

Agar colonies: Small, brownish-yellow, convex.

Agar slant: Abundant growth with greenish fluorescence.

Broth: Turbid.

Litmus milk: Not coagulated.

Potato: Dark brown, becoming chocolate brown.

Indole not formed.

Nitrates not reduced.

The cultures give off an odor resembling jasmine.

Aerobic, facultative.

Optimum temperature 37°C.

Subcutaneous and intravenous inoculations into rabbits cause death in 36 to 48 hours.

Source: Isolated from nasal secretions in ozena.

17. **Pseudomonas chlorina** (Frankland and Frankland) Levine and Soppeland. (*Bacillus chlorinus* G. and P. Frankland, Philos. Trans. Roy. Soc. London, *178*, 1887, 274; *Bacterium chlorinum* Migula, Syst. d. Bakt., *2*, 1900, 471; Levine and Soppeland, Bul. No. 77, Iowa State Agricultural College, 1926.) From Greek, *chloros*, greenish yellow.

Rods: 0.5 by 1.5 micron, occurring singly and in short chains. Non-motile. Gram-negative.

Gelatin stab: Crateriform liquefaction with green fluorescence. Lemon yellow sediment.

Agar colonies: Circular, raised, smooth, amorphous, entire, becoming greenish yellow.

Agar slant: Slightly raised, glistening, the medium becoming light greenish yellow.

Broth: Moderate turbidity. Dirty yellow sediment. No pellicle.

Litmus milk: Peptonized. Litmus reduced.

Potato: Scant, olive green growth.

Indole formed.

Nitrites produced from nitrates.

Starch hydrolyzed.

Blood serum liquefied in 5 days.

Acid from glucose.

Aerobic, facultative.

Optimum temperature 22°C.

Source: Air.

18. **Pseudomonas oleovorans** Lee and Chandler. (Jour. Bact., *41*, 1941, 378.) From M. L. oil destroying.

Short rods: 0.5 by 0.8 to 1.5 microns, occurring singly and in pairs. Motile. Gram-negative.

Gelatin stab: No liquefaction after 6 weeks.

Gelatin colonies: Up to 1 mm. in diameter, fluorescent; similar to agar colonies.

Surface agar colonies: After 24 hours 1 to 2 mm. in diameter, smooth, convex, shiny, opaque, creamy, fluorescent by transmitted light. Edge entire in young colonies.

Deep agar colonies: 0.5 by 1.0 to 1.5 mm., lens-shaped, buff-colored, not fluorescent.

Agar slant: Growth raised, smooth, fluorescent, edge erose.

Broth: After 24 hours moderate turbidity with slight yellowish viscid sediment. No pellicle or ring.

Litmus milk: No change.

Indole not formed.

Potato: Good growth.

Nitrites are produced from nitrates.

Starch is hydrolyzed.

No acid from glucose, lactose, sucrose, galactose, xylose, mannitol, salicin and glycerol.

Equally good growth at 25° and 37°C.

Aerobic.

Distinctive character: The fluorescent quality of the colonies is not imparted to any of the artificial media used.

Source: Isolated from cutting compound (oil-water emulsion) circulating in a machine shop. The oil in this compound may be utilized as a sole source of energy.

Habitat: Probably oil-soaked soils. Abundant in cutting compounds.

19. **Pseudomonas incognita** Chester. (*Bacillus fluorescens incognitus* Wright, Memoirs Nat. Acad. Sci., *7*, 1895, 436; Chester, Determinative Bacteriology, 1901, 323.) From Latin, *in*, not; *cogito*, to think; M. L. unknown.

Short rods, with rounded ends, occurring singly, in pairs and in chains. Motile, possessing a polar flagellum. Gram-negative.

Gelatin colonies: Thin, transparent, slightly granular, becoming greenish. Margin undulate. The medium assumes a blue-green fluorescence.

Gelatin stab: No liquefaction.

Agar slant: Thin, moist, translucent, becoming greenish.

Broth: Turbid, with pellicle, becoming greenish.

Litmus milk: Slightly acid in a month. The litmus is slowly reduced.

Potato: Moist, glistening, spreading, brown.

Indole is formed (trace).

Nitrites are produced from nitrates.

Aerobic, facultative.

Optimum temperature 35°C.

Habitat: Water.

20. **Pseudomonas convexa** Chester. (*Bacillus fluorescens convexus* Wright, Memoirs Nat. Acad. Sci., *7*, 1895, 438; Chester, Determinative Bacteriology, 1901, 325.) From Latin, *convexus*, convex, arched.

Short, thick rods, with rounded ends. Motile, possessing a polar flagellum. Gram-negative.

Gelatin colonies: Circular, convex, glistening, bright greenish, translucent. The medium becomes blue-green, fluorescent.

Gelatin stab: Light green, raised, glistening surface growth. No liquefaction.

Agar slant: Moist, translucent, glistening, light greenish. The medium assumes a greenish color.

Broth: Turbid, becoming greenish.

Litmus milk: No coagulation; alkaline.

Potato: Pale brown, spreading.

Indole not formed.

Nitrites not produced from nitrates.

Aerobic, facultative.

Optimum temperature 30°C.

Habitat: Water.

21. **Pseudomonas mildenbergii** Bergey et al. (Der blaue bacillus, Mildenberg, Cent. f. Bakt., II Abt., *56*, 1922, 309; *Pseudomonas cyanogena* Bergey et al., Manual, 1st ed., 1923, 129; not *Bacillus cyanogenes* Flügge, Die Mikroorganismen, 1886, 201; not *Pseudomonas cyanogenes* Hammer, Dairy Bact., 1928, 70; Bergey et al., Manual, 3rd ed., 1930, 172.) Named for Mildenberg who first isolated this species.

Rods: 0.3 to 0.5 by 1.0 to 3.5 microns, with rounded ends, occurring singly. Motile, possessing polar flagella. Gram-negative.

Gelatin colonies: Circular, lobed, smooth, glistening, slightly raised, steel-blue, entire.

Gelatin stab: No liquefaction.

Agar colonies: Small, circular, yellowish or reddish-yellow, entire, becoming lobed, grayish-green, iridescent. The medium becomes dirty grayish-green.

Agar slant: Smooth, spreading, slimy, glistening, grayish-green to dark green, fluorescent.

Broth: Turbid green, iridescent to opalescent with slimy sediment.

Litmus milk: Not coagulated, blue ring.

Potato: Slimy, glistening, spreading, steel blue.

Indole not formed.

Nitrites not produced from nitrates.

Aerobic, facultative.

Optimum temperature 25°C.

Source: Isolated from air.

2. **Pseudomonas putida** (Trevisan) Migula. (*Bacillus fluorescens putidus* Flügge, Die Mikroorganismen, 2 Aufl., 1886, 288; *Bacillus putidus* Trevisan, I gen. e le specie d. Batteriacee, 1889, 18; Migula, in Engler and Prantl, Die natür. Pflanzenfam., *1*, 1a, 1895, 29; *Bacillus fluorescens putridus* (sic) Kruse, in Flügge, Die Mikroorganismen, *2*, 1896, 292; *Bacterium putidum* Lehmann and Neumann, Bakt. Diag., 1 Aufl., *2*, 1896, 271; *Pseudomonas putrida* (sic) Migula, Syst. d. Bakt., *2*, 1900, 912.) It is not clear which spelling should be used. Either is correct. From Latin *putida* or *putrida*, rotten, stinking.

Rods, with rounded ends. Motile,

possessing polar flagella. Gram-negative.

Gelatin colonies: Small, finely granular, fluorescent with dark center, surrounded by a yellow zone, with pale gray margin.

Gelatin stab: Dirty-white surface growth, becoming greenish, fluorescent. No liquefaction.

Agar colonies: Circular, raised, smooth, amorphous, entire, with fluorescent zone around the periphery.

Agar slant: Yellowish-green layer, becoming fluorescent.

Broth: Turbid, fluorescent.

Litmus milk: Unchanged.

Potato: Thin, gray to brownish, slimy layer.

Cultures give off odor of trimethylamine.

Indole not formed.

Nitrites are produced from nitrates.

Aerobic, facultative.

Optimum temperature 25°C. Will grow at 37°C. (Reid et al., Penn. Agr. Exp. Sta., Bull. 422, 1942, 9).

Distinctive features: Identical with *Pseudomonas fluorescens* Migula according to Lehmann and Neumann (*loc. cit.*) except that it does not liquefy gelatin. See *Pseudomonas eisenbergii* Migula.

Habitat: Putrefying materials; water.

23. **Pseudomonas scissa** (Frankland and Frankland) Migula. (*Bacillus scissus* G. and P. Frankland, Ztschr. f. Hyg., *6*, 1889, 398; Migula, Syst. d. Bakt., *2*, 1900, 927.) From Latin, *scissus*, p.p. of *scindo*, to cut.

Rods: 0.5 by 0.5 to 1.0 micron, with rounded ends, occurring singly, in pairs and in chains; on gelatin, coccus-like. Motile with presumably polar flagella. Gram-negative.

Gelatin colonies: Small, greenish.

Gelatin stab: Thin, smooth, glistening surface growth, irregular, serrate margin. No liquefaction. The medium becomes light green in color.

Agar slant: Smooth, glistening, lobed. The medium assumes a greenish color.

Broth: Turbid, with whitish sediment.

Litmus milk: Not coagulated.

Potato: Glistening, reddish-brown growth.

Indole not formed.

Nitrites produced from nitrates.

Aerobic, facultative.

Optimum temperature 20°C.

Distinctive characters: Resembles *Pseudomonas viscosa* Migula.

Source: Found in water and soils in Kent, England.

Habitat: Water and soil.

24. **Pseudomonas ovalis** Chester. (*Bacillus fluorescens ovalis* Ravenel, Memoirs Nat. Acad. Sci., *8*, 1896, 9; Chester, Determinative Bacteriology, 1901, 325; not *Bacillus ovalis* Wright, Memoirs Nat. Acad. Sci., *7*, 1895, 435.) From *ovum*, egg; M. L. oval.

Rods: 0.3 to 0.7 by 0.7 to 1.3 microns, occurring singly. Motile, possessing a single polar flagellum. Gram-negative.

Gelatin colonies: Irregular, lobate, slightly granular.

Gelatin stab: No liquefaction.

Agar colonies: Circular, opaque, entire, greenish fluorescence.

Agar slant: Thick, white, becoming greenish, fluorescent.

Broth: Turbid, with pellicle.

Litmus milk: No coagulation; alkaline.

Potato: Luxuriant, dirty-brown.

Indole not formed.

Nitrites not produced from nitrates.

Starch not hydrolyzed.

Blood serum not liquefied.

Acid from glucose.

Aerobic, facultative.

Optimum temperature 25°C.

Habitat: Soil. Has been found in intestinal canal.

25. **Pseudomonas striata** Chester. (*Bacillus striatus viridis* Ravenel, Memoirs Nat. Acad. Sci., *8*, 1896, 22; Chester, Determinative Bacteriology, 1901, 325.) From Latin, *strio*, streak, groove.

Slender rods, of variable lengths, stain-

ing irregularly, occurring singly and in pairs. Motile, possessing polar flagella. Gram-negative.

Gelatin colonies: Circular, yellowish, with filamentous border.

Gelatin stab: Raised, white surface growth. No liquefaction.

Agar slant: Thin, yellowish-green, smooth, glistening.

Broth: Turbid, becoming slightly greenish.

Litmus milk: No coagulation; becoming alkaline; litmus reduced.

Potato: Moist, glistening, becoming chocolate-brown.

Indole is formed.

Nitrites are produced from nitrates.

Aerobic.

Optimum temperature 25°C.

Habitat: Soil.

26. **Pseudomonas denitrificans** Bergey et al. (*Bacillus denitrificans fluorescens* Christensen, Cent. f. Bakt., II Abt., *11*, 1903, 190; Bergey et al., Manual, 1st ed., 1923, 131.) From Latin, *de*, from, out of; *nitrum*, soda, nitre; M. L. denitrifying.

Rods: 0.5 to 0.7 by 0.5 to 1.25 microns, occurring singly and in pairs in large, slimy masses. Motile. Gram-negative.

Gelatin colonies: Small, circular, contoured, raised, moist, pearly-gray, glistening.

Gelatin stab: Whitish, lobed surface growth. Yellowish-green growth in stab. No liquefaction.

Agar colonies: Pearly white, circular, entire.

Agar slant: Broad, whitish, contoured, moist, entire.

Broth: Turbid, with thick, wrinkled pellicle.

Litmus milk: Not coagulated.

Potato: Reddish-gray layer.

Indole not formed.

Nitrates reduced with production of nitrogen.

Aerobic, facultative.

Optimum temperature 25°C.

Habitat: Soil.

27. **Pseudomonas solaniolens** Paine. (Rept. Int. Conf. Phytopath. and Econ. Ent. Holland, 1923, 77; *Phytomonas solaniolens* Bergey et al., Manual, 3rd ed., 1930, 274.) From M. L. *Solanum*, a generic name.

Small oval rods: Motile with a polar flagellum. Gram-negative.

Produces an iridescence in gelatin.

Gelatin: No liquefaction.

Gelatin colonies: Round. Iridescence in medium.

Agar colonies: Pale buff.

Litmus milk: Curd, with no sign of digestion.

Potato: Pale buff-colored growth, no change in medium.

Nitrites not produced from nitrates.

Acid but not gas from glucose. No acid or gas from lactose, sucrose, mannitol or glycerol.

Starch: Action feeble.

Optimum temperature 20° to 30°C.

Aerobic, facultative.

Source: Isolated from potato showing internal rust spots.

28. **Pseudomonas eisenbergii** Migula. (*Bacillus fluorescens non liquefaciens* Eisenberg, Bakt. Diag., 3 Aufl., 1891, 145; *Bacillus fluorescens immobilis* Kruse, in Flügge, Die Mikroorganismen, *2*, 1896, 294; Migula, Syst. d. Bakt., *2*, 1900, 913; *Bacterium immobile* Chester, Man. Determ. Bact., 1901, 180; *Pseudomonas nonliquefaciens* Bergey et al., Manual, 1st ed., 1923, 132.) Named for Eisenberg, the bacteriologist who first reported this species.

Short, slender rods, with rounded ends, occurring singly. Non-motile. Kruse (*loc. cit.*, p. 293) lists the motile form of this organism as *Bacillus fluorescens non liquefaciens*. Gram-negative.

Gelatin colonies: Fern-like surface colonies. Medium around colonies has a pearly luster.

Gelatin stab: Surface growth has fluorescent shimmer. No liquefaction.

Agar slant: Greenish layer.

Broth: Turbid, fluorescent.

Litmus milk: Unchanged.

Potato: Diffuse, brownish layer. Medium acquires a grayish-blue color.

Indole is not formed.

Nitrites produced from nitrates.

Acid from glucose.

Blood serum liquefied.

Aerobic, facultative.

Optimum temperature 25°C.

Not pathogenic.

Habitat: Water.

29. **Pseudomonas putrefaciens** (Derby and Hammer) Long and Hammer. (*Achromobacter putrefaciens* Derby and Hammer, Iowa Agr. Exp. Sta. Res. Bul. 145, 1931, 401; Long and Hammer, Jour. Bact., *41*, 1941, 100.) From Latin, *putrida*, rotten, stinking; *faciens*, making.

Rods: 0.5 to 1.0 by 1.1 to 4.0 microns, occurring singly and in pairs. Motile, with a single flagellum. Gram-negative.

Gelatin stab: Rapid, saccate to stratiform liquefaction, with reddish-brown sediment in the liquefied portion.

Agar colony: Circular, smooth, glistening, slightly raised, somewhat transparent, with brownish tinge.

Agar slant: Echinulate, slightly reddish-brown, viscous.

Broth: Turbid, with thin, gray pellicle, and reddish-brown sediment.

Litmus milk: Rapid reduction and proteolysis with odor of putrefaction.

Potato: Echinulate, smooth, glistening, viscous, reddish-brown.

Indole not produced.

Nitrites are produced from nitrates.

Acid from maltose and sucrose. No action on glucose, fructose, galactose, arabinose, lactose, raffinose, dextrin, inulin, salicin, amygdalin, glycerol.

Ammonia is formed.

Aerobic, facultative.

Optimum temperature 21°C.

Source: Isolated from tainted butter.

Habitat: Milk, cream, butter, water, soil, creamery equipment (Long and Hammer, *loc. cit.*; Claydon and Hammer, Iowa Agr. Exp. Sta., Res. Bull. 267, 1939.)

30. **Pseudomonas mephitica** Claydon and Hammer. (Jour. Bact., *37*, 1939, 254.) From Latin, *mephitis*, pestilential, malodorous; M.L. *Mephitis*, a generic name.

Rods: 0.5 to 1.0 by 1.5 to 14.0 microns, occurring singly, in pairs and in chains. Actively motile with a polar flagellum. Gram-negative.

Gelatin: Slow liquefaction.

Agar colonies: Convex, circular, about 3 mm. in diameter, shiny, grayish white, edge entire, of the consistency of bread dough.

Agar slant: Growth grayish-white, wrinkled, echinulate. After 1 or 2 days, a skunk-like odor develops.

Broth: Turbid. Sediment. White pellicle.

Potato: Growth echinulate, shiny, brownish.

Litmus milk: A skunk-like odor develops in 1 to 2 days. Grayish blue surface ring in about 3 days. Alkaline in 7 to 10 days. In two weeks complete reduction. Slight proteolysis and viscosity.

Hydrogen sulfide not produced.

Indole not formed.

Nitrites produced from nitrates.

Acid but not gas produced slowly from glucose, fructose, maltose, and sucrose. No acid from arabinose, dextrin, galactose, glycerol, lactose, mannitol, raffinose or salicin.

Aerobic, facultative.

Optimum temperature 21°C. Growth slight at 5° and 30°C. No growth at 37°C.

Source: Several cultures isolated from butter having a skunk-like odor.

Habitat: Probably from water.

31. **Pseudomonas geniculata** (Wright) Chester. (*Bacillus geniculatus* Wright, Memoirs Nat. Acad. Sci., *7*, 1895, 459; Chester, Man. Determ. Bact., 1901, 313; *Achromobacter geniculatum* Bergey et al., Manual, 1st ed., 1923, 146.) From Latin,

geniculatus, p.p. of *geniculo*, knotted, jointed.

Medium-sized rods, occurring singly, in pairs and chains, motile, possessing polar flagella. Gram-negative.

Gelatin colonies: Circular, whitish, translucent. Deep colonies yellowish.

Gelatin stab: Infundibuliform liquefaction. Sediment light pink.

Agar slant: Grayish, glistening, translucent, limited, becoming brownish-gray.

Broth: Turbid, with slight gray pellicle and sediment.

Litmus milk: Alkaline; reduction of litmus; slight coagulation.

Potato: Thin, brownish, moist, glistening, viscid.

Indole not formed.

Nitrites not produced from nitrates.

Aerobic, facultative.

Optimum temperature 20° to 25°C.

Habitat: Water.

32. **Pseudomonas fragi** (Eichholz) Huss *emend.* Hussong, Long and Hammer. (*Bacterium fragi* Eichholz, Cent. f. Bakt., II Abt., *9*, 1902, 425; Huss, Cent. f. Bakt., II Abt., *19*, 1907, 661; Hussong, Long and Hammer, Iowa Agr. Exp. Sta. Res. Bull. 225, 1937, 122; also see Long and Hammer, Jour. Dairy Sci., *20*, 1937, 448.) From Latin *fragum*, strawberry.

Description from Hussong, Long and Hammer, *loc. cit.*

Rods: 0.5 to 1.0 by 0.75 to 4.0 microns, occurring singly, in pairs and in chains. Motile with a polar flagellum. Gram-negative.

Gelatin: Crateriform to stratiform liquefaction in 3 to 4 days.

Agar colonies: Convex, glistening, generally butyrous, occasionally viscid. Rough, smooth and intermediate forms are recognized in the description quoted. The rough forms are less proteolytic, and less active in the hydrolysis of fats.

Agar slant: Growth abundant, spreading, raised, white, shiny, generally butyrous. Sweet ester-like odor resembling that of the flower of the May apple.

Broth: Turbidity and sediment with a thin pellicle.

Litmus milk: Acid ring followed by acid coagulum at surface. Complete coagulation in 2 to 3 weeks, some digestion. Characteristic May apple or strawberry odor.

Potato: Growth echinulate to arborescent, raised, glistening, white, becoming brownish.

Indole not produced.

Nitrites not produced from nitrates.

Ammonia produced from peptone.

Hydrogen sulfide not produced.

Acid from glucose and galactose, sometimes arabinose. No acid from glycerol, inulin, lactose, fructose, maltose, mannitol, raffinose, salicin and sucrose.

No acetylmethylcarbinol produced.

Fat is generally hydrolyzed.

Aerobic.

Grows from 10° to 30°C. No growth at 37°C. Very sensitive to heat.

Source: Isolated from milk and other dairy products, dairy utensils, water, etc.

Habitat: Soil and water. Widely distributed (Morrison and Hammer, Jour. Dairy Sci., *24*, 1941, 9).

Hussong (Thesis, Iowa State College, 1932) regards *Bacterium fragi* Eichholz (*loc. cit.*) as the R type, *Pseudomonas fragariae I* Gruber (Cent. f. Bakt., II Abt., *9*, 1902, 705) as the O form, and *Pseudomonas fragariae II* Gruber (Cent. f. Bakt., II Abt., *14*, 1905, 122) as the S form of the same organism. He makes no mention of *Pseudomonas fragaroidea* Huss (*loc. cit.*) which from its description would belong to the smooth type. A brief characterization of each of these organisms follows: (1) *Bacterium fragi* came from milk as drawn from an individual cow; it does not liquefy gelatin, exhibits no fluorescence, is strongly alkaline in litmus milk, and does not grow at 37°C, (2) *Pseudomonas fragariae I* came from fodder beets; it does not liquefy gelatin, has weak blue-greenish fluorescence, is weakly alkaline in milk, and grows at 37°C, (3) *Pseudomonas fragariae II* came from pasteurized milk; it liquefies gelatin, coagulates milk, and does not grow at 37°C, (4) *Pseudomonas*

fragaroidea came from butter; it liquefies gelatin, coagulates milk, and grows at 37°C.

*33. **Pseudomonas nebulosa** (Wright) Chester. (*Bacillus nebulosus* Wright, Memoirs Nat. Acad. Sci., *7*, 1895, 465; Chester, Man. Determ. Bact., 1901, 311; *Achromobacter nebulosum* Bergey et al., Manual, 1st ed., 1923, 145; not *Bacillus nebulosus* Hallé, Thèse de Paris, 1898; not *Bacillus nebulosus* Vincent, Ann. Inst. Past., *21*, 1907, 69; not *Bacillus nebulosus* Migula, Syst. d. Bakt., *2*, 1900, 844; not *Bacillus nebulosus* Goresline, Jour. Bact., *27*, 1934, 52.) From Latin, *nebula*, mist.

Medium-sized rods, occurring singly. Motile, possessing polar flagella. Gram-negative.

Gelatin colonies: Thin, circular, gray, translucent, hazy, with white center.

Gelatin stab: Crateriform liquefaction.

Agar slant: Thin, transparent streak.

Broth: Turbid, with gray sediment.

Litmus milk: Alkaline; reduction of litmus.

Potato: Scanty growth.

Indole not formed.

Nitrites not produced from nitrates.

Sugar gelatin in deep stab: Fair growth, with some gas formation.

Aerobic, facultative.

Optimum temperature 30° to 35°C.

Habitat: Water.

Probable synonym: *Pseudomonas centrifugans* Chester. (Man. Determ. Bact., 1901, 312; *Bacillus centrifugans* Wright, Mem. Nat. Acad. Sci., *7*, 1895, 462.)

34. **Pseudomonas coadunata** (Wright) Chester. (*Bacillus coadunatus* Wright, Memoirs Nat. Acad. Sci., *7*, 1895, 460; Chester, Man. Determ. Bact., 1901, 310; *Achromobacter coadunatum* Bergey et al., Manual, 1923, 147.) 1st ed., From Latin, *coadunatus*, to unite closely.

Medium-sized rods, with rounded ends, occurring singly, in pairs and in chains. Motile, possessing a polar flagellum. Gram-negative.

Gelatin colonies: Circular, brownish, dense.

Gelatin stab: Crateriform to stratiform liquefaction.

Agar slant: Gray, translucent, spreading.

Broth: Turbid, with gray pellicle and sediment. The medium has a slight greenish tint.

Litmus milk: Acid; coagulated.

Indole is formed.

Nitrites not produced from nitrates.

Sugar gelatin in deep stab: Good growth of discreet and confluent whitish colonies. Marked gas production; no liquefaction.

Aerobic, facultative.

Optimum temperature 20° to 25°C.

Habitat: Water.

35. **Pseudomonas multistriata** (Wright) Chester. (*Bacillus multistriatus* Wright, Memoirs Nat. Acad. Sci., *7*, 1895, 462; Chester, Man. Determ. Bact., 1901, 310; *Achromobacter multistriatum* Bergey et al., Manual, 1st ed., 1923, 147.) From Latin, *multus*, many, much; *striatus*, grooved.

Medium-sized rods, with rounded ends, occurring singly and in pairs. Motile, possessing polar flagella. Gram-negative.

Gelatin colonies: Circular, grayish-white, translucent.

Gelatin stab: Crateriform liquefaction.

Agar slant: Narrow, translucent, grayish streak.

Broth: Turbid.

Litmus milk: Slightly acid; coagulated.

Potato: Grayish to creamy, thick, glistening, viscid, spreading.

Indole not formed.

Nitrites not produced from nitrates.

Sugar gelatin in deep stab: Vigorous growth with marked gas production; also liquefaction.

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*Prof. E. R. Hitchner, Univ. of Maine, Orono, Maine assisted in rearranging the descriptions of the acid and gas producing pseudomonads (*Aeromonas*), April, 1943.

Aerobic, facultative.

Optimum temperature 20° to 25°C.

Habitat: Water.

36. **Pseudomonas punctata** (Zimmermann) Chester. (*Bacillus punctatus* Zimmermann, Bakt. unserer Trink- und Nutzwässer, Chemnitz, *1*, 1890, 38; *Bacillus aquatilis communis* Kruse, in Flügge, Die Mikroorganismen, *2*, 1896, 315; *Bacterium punctatum* Lehmann and Neumann, Bakt. Diag., 1 Aufl., *2*, 1896, 238; Chester, Man. Determ. Bact., 1901, 313; *Achromobacter punctatum* Bergey et al., Manual, 1st ed., 1923, 147.) From Latin, *punctus*, a puncture, point; M. L. punctate, dotted.

Rods: 0.7 by 1.0 to 1.5 micron, occurring singly, in pairs and in chains. Motile with a single polar flagellum. Gram-negative.

Gelatin colonies: Small, circular, gray, erose to filamentous, punctiform.

Gelatin stab: Crateriform liquefaction. No pellicle.

Agar slant: Gray, smooth, filamentous.

Broth: Turbid with delicate pellicle.

Litmus milk: Acid; coagulated; peptonized.

Potato: Brownish-yellow to brownish-red color.

Indole is formed.

Nitrites not produced from nitrates.

Hydrogen sulfide is formed.

Acid and gas from glucose.

Aerobic, facultative.

Optimum temperature 25° to 30°C.

Source: Common in the Chemnitz tap water.

Habitat: Cause of a hemorrhagic septicemia in carp (*Cyprinus*) (Schäperclaus, Ztschr. f. Fischerei, *28*, 1930; Cent. f. Bakt., II Abt., *105*, 1942, 49).

37. **Pseudomonas hydrophila** (Chester) *comb. nov.* (*Bacillus hydrophilus fuscus* Sanarelli, Cent. f. Bakt., *9*, 1891, 222; *Bacterium hydrophilus fuscus* Chester, Delaware College Agr. Expt. Sta., 9th Ann. Rept., 1897, 92; *Bacillus hydrophilus* Chester, Manual Determ. Bact., 1901, 235; *Bacterium hydrophilum* Weldin and Levine, Bact. Abs., *7*, 1923, 14; *Proteus hydrophilus* Bergey et al., Manual, 1st ed., 1923, 211; *Aeromonas hydrophila* Stanier, Jour. Bact., *46*, 1943, 213.) From Greek, *hydōr*, water, *philus*, loving; M. L. water-loving.

It was reported by Russell, Jour. Amer. Med. Assoc., *30*, 1898, 1442 and later by Emerson and Norris, Jour. Exper. Med., *7*, 1905, 32 who made a complete study of its properties and its pathogenic action.

Weldin (Iowa State College Jour. Sci., *1*, 1927, 151) considers *Bacillus ranicida* Ernst (Beiträge z. path. Anat. u. z. Allgemein. Pathol., *8*, 1890, 204; *Bacterium ranicida* Chester, Ann. Rept. Del. Col. Agr. Exp. Sta., *9*, 1897, 141) a possible synonym of *Proteus hydrophilus*.

Rods: 0.6 by 1.3 microns, occurring singly and in chains. Motile, with a single polar flagellum (Kulp and Borden, Jour. of Bact., *44*, 1942, 673). Gram-negative.

Gelatin colonies: Small, circular, gray, translucent, stippled.

Gelatin stab: Napiform liquefaction.

Agar colonies: Whitish, raised, moist, stippled.

Agar slant: Thin, whitish, glassy, spreading, becoming yellowish.

Broth: Turbid, with heavy pellicle.

Litmus milk: Acid; coagulated; peptonized.

Potato: Yellowish-brown, moist slightly raised.

Indole is formed.

Nitrites produced from nitrates.

Acid and gas from glucose, maltose, sucrose and mannitol. No action on lactose.

Gas ratio $H_2:CO_2 = 1:4.71$. Methyl red negative, acetylmethylcarbinol positive, indol negative, citrate positive (Speck and Stark, Jour. Bact., *44*, 1942, 697).

Aerobic, facultative.

Optimum temperature 37°C.

Pathogenic for frogs, salamanders, fish,

mice, guinea pigs and rabbits, causing hemorrhagic septicemia.

Distinctive characters: Much like *Pseudomonas punctata* (Guthrie and Hitchner, Jour. Bact., *45*, 1943, 52).

Source: Isolated from frogs dead of septicemia (red leg).

Habitat: Water and infected fresh water animals.

38. **Pseudomonas ichthyosmia** (Hammer) *comb. nov.* (*Bacillus ichthyosmius* Hammer, Iowa Agr. Sta. Res. Bul. 38, 1917; *Escherichia ichthyosmia* Bergey et al., Manual, 1st ed., 1923, 201; *Proteus ichthyosmius* Bergey et al., Manual, 4th ed., 1934, 364.) From Greek, *ichthys*, a fish; *osmē*, an odor.

Rods: 0.6 to 0.8 by 1.0 to 2.1 microns, occur singly. Motile with a single polar flagellum (Breed). Gram-negative.

Gelatin stab: Liquefaction.

Agar colonies: Small, white, becoming darker with age.

Agar slant: Dirty white, viscid growth.

Broth: Turbid with gray sediment.

Litmus milk: Acid. Litmus reduced. Cultures have fishy odor.

Potato: Thin, glistening layer.

Indole is formed.

Nitrites produced from nitrates.

Acid and gas from glucose, fructose, galactose, maltose, sucrose, glycerol, salicin and mannitol. Lactose, dulcitol, raffinose and inulin not fermented.

Aerobic, facultative.

Optimum temperature 20°C.

Source: Isolated from can of evaporated milk having a fishy odor.

Habitat: Not known.

39. **Pseudomonas ambigua** (Wright) Chester. (*Bacillus ambiguus* Wright, Memoirs Nat. Acad. Sci., *7*, 1895, 439; Chester, Man. Determ. Bact., 1901, 308; *Achromobacter ambiguum* Bergey et al., Manual, 1st ed., 1923, 148.) From Latin, *ambiguus*, doubtful, uncertain.

Small rods, with rounded ends, occurring singly, in pairs and in chains. Motile, possessing a polar flagellum. Gram-negative.

Gelatin colonies: Gray, translucent, slightly raised, irregular, radiate, with transparent margin.

Gelatin stab: No liquefaction.

Agar slant: Gray, limited, entire.

Broth: Turbid, with gray sediment.

Litmus milk: Acid, slowly coagulated.

Potato: Gray to creamy, viscid, spreading.

Indole is formed.

Nitrites not produced from nitrates.

Aerobic, facultative.

Optimum temperature 30° to 35°C.

Habitat: Water.

40. **Pseudomonas sinuosa** (Wright) Chester. (*Bacillus sinuosus* Wright, Memoirs Nat. Acad. Sci., *7*, 1895, 440; Chester, Man. Determ. Bact., 1901, 307; *Achromobacter sinosum* (sic) Bergey et al., Manual, 1st ed., 1923, 148.) From Latin, *sinuosus*, full of bends, sinuous.

Medium-sized rods, with rounded ends, occurring singly, in pairs and in chains. Motile, possessing two to four polar flagella. Gram-negative.

Gelatin colonies: Thin, translucent, irregular, center brownish.

Gelatin stab: Grayish-white, glistening, translucent. No liquefaction.

Agar slant: Scanty, grayish growth.

Broth: Turbid, with gray sediment.

Litmus milk: Unchanged.

Potato: Grayish-white, moist, spreading.

Indole is formed.

Nitrites not produced from nitrates.

Aerobic, facultative.

Optimum temperature 30° to 35°C.

Habitat: Water.

41. **Pseudomonas cruciviae** Gray and Thornton. (Gray and Thornton, Cent. f. Bakt., II Abt., *73*, 1928, 91; *Achromobacter cruciviae* Bergey et al., Manual, 3rd ed., 1930, 218.) From Latin, *crux*, a cross, *via*, way, road; from Waycross, a place name.

Rods: 1.0 by 1.0 to 3.0 microns, occurring singly and in pairs. Motile with one to five polar flagella. Gram-negative.

Gelatin colonies: Circular, white with buff center, convex, smooth, undulate.

Gelatin stab: No liquefaction.

Agar colonies: Circular or amoeboid, white to buff, flat to convex, smooth, entire.

Agar slant: Filiform, pale buff, raised, smooth, undulate.

Broth: Turbid.

Nitrites not produced from nitrates.

Starch not hydrolyzed.

No acid in carbohydrate media.

Attack phenol and *m*-cresol.

Aerobic, facultative.

Optimum temperature 30 to 35°C.

Habitat: Soil.

42. **Pseudomonas rugosa** (Wright) Chester. (*Bacillus rugosus* Wright, Memoirs Nat. Acad. Sci., *7*, 1895, 438; not *Bacillus rugosus* Henrici, Arb. Bakt. Inst. Tech. Hochsch. Karlsruhe, *1*, 1894, 28; not *Bacillus rugosus* Chester, Determinative Bacteriology, 1901, 220; Chester, Determinative Bacteriology, 1901, 323.) From Latin, *rugosus*, wrinkled.

Small rods, with rounded ends, occurring singly, in pairs and in chains. Motile, possessing one to four polar flagella. Gram-negative.

Gelatin colonies: Grayish, translucent, slightly raised, irregular, sinuous, radiately erose to entire.

Gelatin stab: Dense, grayish-green, limited, wrinkled, reticulate surface growth. No liquefaction.

Agar slant: Grayish-white, limited, slightly wrinkled, translucent.

Broth: Turbid, with grayish pellicle and sediment.

Litmus milk: Acid, coagulated.

Potato: Moist, glistening, brown.

Indole is formed.

Nitrites not produced from nitrates.

Aerobic.

Optimum temperature 30°C.

Habitat: Water.

43. **Pseudomonas desmolyticum** Gray and Thornton. (Gray and Thornton, Cent. f. Bakt., II Abt., *73*, 1928, 90; *Achromobacter desmolyticum* Bergey et al., Manual, 3rd ed., 1930, 217.) From Greek *desmos*, bond, band; *lytikos*, able to dissolve.

Rods: 0.7 to 0.8 by 2.0 to 3.0 microns, occurring singly and in pairs. Motile, with one to five polar flagella. Gram-negative.

Gelatin colonies: Circular, gray to buff, raised or umbonate. Smooth, glistening, entire.

Gelatin stab: No liquefaction.

Agar colonies: Circular or amoeboid, whitish, flat or convex, smooth, translucent to opaque, entire.

Agar slant: Filiform, pale buff, raised, smooth, undulate.

Broth: Turbid.

Nitrites produced from nitrates.

Starch not hydrolyzed.

Acid from glucose.

Attack phenol and naphthalene.

Aerobic, facultative.

Optimum temperature 25°C.

Habitat: Soil.

44. **Pseudomonas rathonis** Gray and Thornton. (Gray and Thornton, Cent. f. Bakt., II Abt., *73*, 1928, 90; *Achromobacter rathonis* Bergey et al., Manual, 3rd ed., 1930, 216.) From M. L. of Ratho Park (Edinburgh).

Small rods: 0.5 to 1.0 by 1.0 to 3.0 microns. Motile, with polar flagella. Gram-negative.

Gelatin colonies: Circular, white, raised, smooth, glistening, undulate.

Gelatin stab: No liquefaction.

Agar colonies: Circular, buff, flat, smooth, glistening, entire.

Agar slant: Filiform, pale buff, convex, smooth, glistening, undulate.

Broth: Turbid, with pellicle.

Nitrites produced from nitrates.

Starch hydrolyzed.

Acid from glucose and glycerol.

Attack phenol and cresol at times, also naphthalene.

Aerobic, facultative.

Optimum temperature 25°C.

Habitat: Manure and soil.

45. **Pseudomonas dacunhae** Gray and Thornton. (Gray and Thornton, Cent. f. Bakt., II Abt., *73*, 1928, 90; *Achromobacter dacunhae* Bergey et al., Manual, 3rd ed., 1930, 217.) From M. L. from the Island of d'Acunha.

Rods: 0.5 to 0.8 by 1.5 to 3.0 microns. Motile with one to six polar flagella. Gram-negative.

Gelatin colonies: Circular, whitish, raised, smooth, glistening, undulate.

Gelatin stab: No liquefaction.

Agar colonies: Circular to amoeboid, white, flat, glistening, opaque, entire.

Agar slant: Filiform, pale buff, raised, smooth, glistening, undulate.

Broth: Turbid.

Nitrites produced from nitrates.

Starch not hydrolyzed.

No acid from carbohydrate media.

Attack phenol.

Aerobic, facultative.

Optimum temperature 25°C.

Habitat: Soil.

46. **Pseudomonas arvilla** Gray and Thornton. (Gray and Thornton, Cent. f. Bakt., II Abt., *73*, 1928, 90; *Achromobacter arvillum* Bergey et al., Manual, 3rd ed., 1930, 217.) From Latin, *arvum*, an arable field; M. L. dim. a little field.

Rods: 0.5 to 0.7 by 2.0 to 3.0 microns. Motile with one to five polar flagella. Gram-negative.

Gelatin colonies: Circular, whitish, convex, smooth, glistening, lobate.

Gelatin stab: No liquefaction.

Agar colonies: Circular or amoeboid, white to buff, flat to convex, smooth, glistening, opaque, entire.

Agar slant: Filiform, whitish, concave, smooth, ringed, entire.

Broth: Turbid.

Nitrites not produced from nitrates.

Starch not hydrolyzed.

Acid from glucose.

Attacks naphthalene.

Aerobic, facultative.

Optimum temperature 25°C.

Habitat: Soil.

47. **Pseudomonas salopium** Gray and Thornton. (Gray and Thornton, Cent. f. Bakt., II Abt., *73*, 1928, 91; *Achromobacter salopium* Bergey et al., Manual, 3rd ed., 1930, 219.) From Latin, *Salop*, Shropshire.

Rods: 0.7 to 1.0 by 1.0 to 3.0 microns, occurring singly and in pairs. Motile with one to six polar flagella. Gram-negative.

Gelatin colonies: Circular, grayish-buff, flat, rugose or ringed, translucent border.

Gelatin stab: No liquefaction.

Agar colonies: Circular or amoeboid, white to buff, flat to convex, smooth, glistening, translucent border, entire.

Agar slant: Filiform, whitish, raised, smooth, glistening, lobate.

Broth: Turbid with pellicle.

Nitrites not produced from nitrates.

Starch not hydrolyzed.

Acid from glucose and sucrose.

Attacks naphthalene.

Aerobic, facultative.

Optimum temperature 25°C.

Habitat: Soil.

48. **Pseudomonas minuscula** McBeth. (McBeth, Soil Science, *1*, 1916, 437; *Cellulomonas minuscula* Bergey et al., Manual, 1st ed., 1923, 162.) From Latin dim. rather small.

Rods: 0.5 by 0.9 micron. Motile with one to two polar flagella. Gram-negative.

Gelatin stab: Moderate growth. Slight napiform liquefaction.

Agar colonies: Small, circular, slightly convex, butyrous becoming brittle, grayish-white, finely granular, entire.

Agar slant: Moderate, flat, grayish-white.

Broth: Turbid.

Litmus milk: Acid, not digested.
Potato: No apparent growth.
Indole is formed.
Nitrites produced from nitrates.
Ammonia is produced.
Acid from glucose, lactose, maltose, sucrose and starch.
Aerobic, facultative.
Optimum temperature 20°C.
Habitat: Soil.

49. **Pseudomonas tralucida** Kellerman et al. (Kellerman, McBeth Scales and Smith, Cent. f. Bakt., II Abt., *39*, 1913, 37; *Cellulomonas tralucida* Bergey et al., Manual 1st ed., 1923, 163.) From Latin, clear, transparent.

Rods: 0.6 by 1.2 microns. Motile with one or two polar flagella. Gram-negative.
Gelatin stab: No liquefaction.
Agar slant: Scant, grayish growth.
Broth: Turbid.
Litmus milk: Acid.
Potato: No growth.
Indole not formed.
Nitrites produced from nitrates.
Ammonia not produced.
Acid from glucose, maltose, lactose, sucrose, starch, glycerol and mannitol.
Aerobic, facultative.
Optimum temperature 20°C.
Habitat: Soil.

50. **Pseudomonas mira** McBeth. (McBeth, Soil Science, *1*, 1916, 437; *Cellulomonas mira* Bergey et al., Manual, 1st ed., 1923, 165.) From Latin, *mirus*, wonderful, extraordinary.

Rods: 0.4 by 1.6 microns. Motile with a single polar flagellum. Gram-negative.
Gelatin stab: Good growth. No liquefaction.
Agar colonies: Circular, convex, grayish-white, granular, lacerate.
Agar slant: Moderate, flat, grayish-white, somewhat iridescent.
Broth: Turbid.
Litmus milk: Alkaline.
Potato: Moderate, grayish-white.
Indole not formed.
Nitrites produced from nitrates.
Ammonia is produced.
Acid from glucose, maltose, lactose, sucrose, starch, glycerol and mannitol.
Aerobic, facultative.
Optimum temperature 20°C.
Habitat: Soil.

51. **Pseudomonas lindneri** Kluyver and Hoppenbrouwers. (Lindner, 50 Jubiläumsber. Westpreuss. Bot.-Zool. Vereins, 1928, 253; *Termobacterium mobile* Lindner, Atlas d. Mikrosk. Grundl. d. Gärungsk., 3 Aufl., *2*, 1928, Taf. 68; Kluyver and Hoppenbrouwers, Arch. f. Mikrobiol., *2*, 1931, 259; *Achromobacter mobile* Kluyver and Hoppenbrouwers, *ibid.*, 258; not *Pseudomonas mobilis* Migula, Syst. d. Bakt., *2*, 1900, 923.) Named for Lindner, the German bacteriologist who first studied this organism.

Short rods 1.4 to 2.0 by 4.0 to 5.0 microns. Occurring singly, in pairs and short chains. Motile with a single polar flagellum. Gram-negative.
Peptone gelatin: Poor growth.
Peptone agar: Poor growth.
Wort agar: White, round, raised colonies, 1 mm. in diameter. Good growth. Still better where 2 per cent sucrose, or yeast extract with sucrose is added. Chalk added to neutralize acid.
Broth: Poor growth in peptone or yeast extract broth unless sugars are added.
Carbon dioxide, ethyl alcohol and some lactic acid produced from glucose and fructose, but not from mannose. May or may not ferment sucrose. May produce as much as 10 per cent alcohol.
Catalase produced.
Anaerobic, facultative.
Optimum temperature 30°C.
Distinctive character: The fermentation resembles the alcoholic fermentation produced by yeasts.
Source: Isolated from the fermenting sap (pulque) of *Agave americana* in Mexico.
Habitat: Fermenting plant juices in tropical countries (Mexico).

52. **Pseudomonas membranoformis** (Zobell and Allen) Zobell. (*Achromobacter membranoformis* Zobell and Allen, Jour. Bact., *29*, 1935, 246; Zobell, Jour. Bact., *46*, 1943, 45). From Latin *membrana*, membrane, and *forma* having the form of.

Rods: 0.9 to 1.2 by 3.5 to 4.8 microns, occurring singly and in pairs. Motile with lophotrichous flagella. Encapsulated. Gram-negative.

Gelatin stab: Growth filiform, best at top, with slow crateriform liquefaction.

Agar colonies: Circular, 1.0 to 2.5 mm, with crinkled surface.

Agar slant: Moderate, beaded, raised growth. Membranous consistency. Becomes browned with age.

Broth: Slight turbidity, flocculent sediment, film of growth on walls of test tube.

Milk: No growth.

Potato: No growth.

Indole not formed.

Nitrites not produced from nitrates.

No H_2S produced.

Acid but not gas from glucose, sucrose, dextrin and mannitol. No acid from lactose or xylose.

No diastatic action.

Optimum temperature 20° to 25°C.

Aerobic.

Source: Sea water.

Habitat: Sea water.

53. **Pseudomonas marinoglutinosa** (Zobell and Allen) Zobell. (*Achromobacter marinoglutinosus* Zobell and Allen, Jour. Bact., *29*, 1935, 246; Zobell, Jour. Bact., *46*, 1943, 45). From Latin *marinus*, pertaining to the sea, and *glutinosus*, full of glue, sticky.

Short rods: 0.7 to 1.0 by 1.8 to 2.4 microns, with rounded ends, occurring singly, in pairs and in clumps. Motile with polar flagella. Staining granular. Encapsulated. Gram-negative.

Gelatin stab: Moderate filiform growth with slight napiform liquefaction. No pigment.

Agar colonies: Round with concentric circles and crinkled radial lines, 1.5 to 5.0 mm. in diameter. No pigment.

Agar slant: Moderate, filiform, flat. Butyrous consistency.

Broth: Moderate clouding, marked ring, adherent film of growth on test tube wall, and flaky sediment.

Milk: No growth.

Potato: No growth.

Indole not formed.

Nitrites not produced from nitrates.

Hydrogen sulfide and ammonia produced from Bacto-tryptone.

Acid but not gas from xylose and dextrin. No acid from glucose, lactose, sucrose and mannitol.

Starch is hydrolyzed.

Optimum temperature 20° to 25°C.

Aerobic, facultative.

Source: Sea water.

Habitat: Sea water.

54. **Pseudomonas gelatica** (Gran) Bergey et al. (*Bacillus gelaticus* Gran, Bergens Museums Aarbog., 1902, 14; *Bacterium gelaticum* Lundestad, Cent. f. Bakt., II Abt., *75*, 1928, 328; Bergey et al., Manual, 3rd ed., 1930, 175.) From French, like gelatin.

Rods, with rounded ends, 0.6 to 1.2 by 1.2 to 2.6 microns, occurring singly, in pairs, and sometimes in short chains. Motile. Gram-negative.

Fish-gelatin colonies: Circular, transparent, glistening, becoming brownish in color.

Fish-gelatin stab: Liquefaction infundibuliform, with greenish color.

Sea-weed agar colonies: Circular, flat, entire, glistening, reddish-brown center with grayish-white periphery. Liquefied.

Fish-agar slant: Flat, transparent streak, with undulate margin, reddish-brown.

Broth: Turbid with flocculent pellicle, and greenish-yellow sediment.

Indole not formed.

Nitrites are produced from nitrates.

Starch hydrolyzed.

No action on sugars.

Anaerobic, facultative.

Optimum temperature 20 to 25°C.

Habitat: Sea water of Norwegian coast.

55. **Pseudomonas calcis** (Drew) Kellerman and Smith. (*Bacterium calcis* Drew, Yearbook Carnegie Inst. Wash., *11*, 1912, 136–144; Kellerman and Smith, Proc. Nat. Acad. Sci., *4*, 1914, 400.) From Latin *calx* (*calc-*), lime.

Ovoid rods, 1.1 by 1.5 to 3 microns, usually single but may form long chains. Actively motile with one polar flagellum. Gram-negative.

Grows best in sea water or 3 per cent salt media. Deposits $CaCO_3$.

Agar colonies: Circular, with finely irregular outline, granular appearance, elevated, spreading; old colonies having brownish tinge in center.

Gelatin stab: Infundibuliform liquefaction.

Gelatin colonies: Small, with liquefaction.

Broth: Good growth especially in presence of potassium nitrate, peptone or calcium malate.

Acid from glucose, mannite and sucrose but not from lactose.

Nitrates reduced to nitrites and ammonia.

Aerobic, facultative.

Optimum temperature 20 to 28°C.

Habitat: Sea water and marine mud.

Bavendamm (Arch. f. Mikrobiol., *3*, 1932, 214) states that *Pseudomonas calcis* is probably synonymous with *Bacterium brandti*, *Bacterium bauri* and *Bacterium feiteli* described by Parlandt (Bull. Jard. imp. Bot. St. Petersburg, *11*, 1911, 97–105).

56. **Pseudomonas calciprecipitans** Molisch. (Cent. f. Bakt., II Abt., *65*, 1925, 130.) From Latin, *calx* (*calc-*), lime; *praecipito*, to cast down headlong, to precipitate.

Thin rods: 0.5 to 0.8 by 1.5 to 3.6 microns, with rounded ends, often staining irregularly. Motile, with one polar flagellum. Gram-negative.

Gelatin colonies: Circular, light brown in color (large colonies show $CaCO_3$ crystals).

Gelatin stab: Surface growth with filiform growth in depth. Liquefaction starts at bottom.

Agar colonies (sea water). Grayish-white, glistening. In two to three weeks crystals of calcium carbonate form in the agar.

Agar slant: Slight, whitish, surface growth, becoming thick, spreading, glistening, with abundant $CaCO_3$ crystals in medium.

Ammonia formed.

Aerobic, facultative.

Optimum temperature 20°C.

Habitat: Sea water.

57. **Pseudomonas ichthyodermis** (Wells Zobell) Zobell and Upham. (*Achromobacter ichthyodermis* Wells and Zobell, Proc. Nat. Acad. Sci., *20*, 123, 1934; Zobell and Upham, Bull. Scripps Inst. Oceanography, *5*, 1944, 246 and 253.) From Greek, *ichthys*, a fish; *derma*, skin.

Small rods, 0.9 to 1.3 by 3 to 5 microns, occurring singly and in pairs. No spores. Encapsulated. Polar flagella. Pleomorphic forms predominate in old cultures. Gram-negative.

Requires sea water following initial isolation. The following differential media are prepared with sea water.

Agar colonies: Glistening, colorless, convex, circular colonies 2 to 4 mm. in diameter.

Agar slants: Abundant, filiform, raised, smooth, opalescent growth.

Gelatin tube: Rapid crateriform liquefaction complete in 5 days at 18°C.

Sea water broth: Turbidity, with pellicle, little granular sediment and no odor.

Milk: No growth. Casein digested when 3 per cent salt is added.

Potato: No growth unless dialyzed in sea water. Then fair growth with no pigment.

Acid from glucose, maltose, sucrose and mannitol but not from lactose or glycerol.

Starch hydrolyzed.

Ammonia liberated from peptone but no hydrogen sulfide produced.

Indole formed in tryptophane sea water broth.

Nitrites produced from nitrates.

Optimum temperature 20 to 25°C.; 30°C. incubation will kill recently isolated organisms.

Aerobic, facultative.

Source: Isolated from diseased kilifish (*Fundulus parvipinnis*).

Habitat: Skin lesions and muscle tissue of infected marine fish.

58. **Pseudomonas nigrifaciens** White. (Scientific Agriculture, *20*, 1940, 643.) From Latin *niger*, black and *faciens*, making.

Rods: 0.3 to 0.7 by 1 to 5 microns, occurring singly or in pairs, and having rounded ends. Actively motile, with a single polar flagellum. Gram-negative.

Gelatin stab: Pigmented surface growth after 24 hours. Slight crateriform liquefaction changing to saccate.

Agar colonies: Circular, convex, smooth, glistening, entire, 2 to 4 mm in diameter. Slight fluorescence in early stages. The medium assumes a brownish color.

Agar slant: Growth filiform, smooth, moist, glistening, with blackish pigmentation at 4° and 15°C. in 48 hrs., the medium turning brownish. Slight fluorescence in early stages.

Broth: Turbid after 24 hours. After 5 to 6 days a black ring and then a pellicle forms, later a black sediment. Medium turns brown.

Litmus milk: A black ring appears after 3 days at 15°C. followed by a pellicle. Litmus is reduced. Alkaline reaction. No coagulation. Digested with a putrid odor.

Indole not formed.

Nitrites not produced from nitrates in 7 days. No gas produced.

Starch is hydrolyzed. Natural fats not hydrolyzed.

Alkaline reaction produced in sucrose, maltose, lactose, glucose, mannitol and raffinose broth (pH 8.2). No gas produced.

Ammonia produced in peptone broth.

Aerobic.

Optimum pH 6.8 to 8.4.

Temperature relations: Minimum 4°C. Optimum 25°C. Maximum 33–35°C.

Distinctive characters: No or slow growth in culture media in the absence of salt. Maximum growth and pigmentation appeared with 1.5 and 2.5 per cent salt. Optimum pigmentation occurs at 4° and 15°C.

Source: Several cultures isolated from samples of discolored butter.

Habitat: Causes a black to reddish-brown discoloration of print butter. Evidently widely distributed in nature.

59. **Pseudomonas beijerinckii** Hof. (Travaux botaniques néerlandais, *32*, 1935, 152.) Named for M. W. Beijerinck, Dutch bacteriologist.

Small rods: Motile with polar flagella.

Gelatin: No liquefaction.

Indole not formed.

Nitrites produced from nitrates by four out of six strains.

Cellulose not decomposed.

Acid from glucose. In yeast-water with 2 per cent glucose and 12 per cent NaCl no gas is produced.

Pigment production: Insoluble purple pigment produced but not in all media; is localized markedly; reduced oxygen tension necessary; optimum pH 8.0; not produced in yeast-water or in peptone-water; produced only when grown in extracts of beans or some other vegetable.

Aerobic.

Source: Six strains isolated from beans preserved with salt.

Habitat: Causes purple discoloration of salted beans.

60. **Pseudomonas salinaria** Harrison and Kennedy. (Harrison and Kennedy, Trans. Royal Soc. of Canada, *16*, 1922, 121; *Serratia salinaria* Bergey et al., Manual, 1st ed., 1923, 93; *Flavobacterium (Halobacterium) salinarium* Elazari-Volcani, Studies on the Microflora of the Dead Sea, Thesis, Hebrew Univ., Jerusalem, 1940, 59.) From Latin, *salinae*, saltworks.

Probable synonym: *Serratia sambharianus* Dixit and Vachna, Current Sci., *11*, 1942, 107 (see Biol. Abs., *17*, 1943, 793). Halophilic growing in 30 per cent salt. From salt lake in India.

Occurs as spheres and rods, 2.0 to 3.0 microns in diameter, 1.0 to 1.6 by 3.0 to 15.0 microns, occurring singly, as ovoid, amoeboid, clavate, cuneate, truncate, spindle, club, pear-shape, and irregular forms. Motile, frequently with a flagellum at each pole. Gram-negative.

Does not grow on ordinary culture media. Grows well on salted fish.

Codfish agar (16 to 30 per cent salt): Growth slow, smooth, raised, coarsely granular, entire, pale pink to scarlet (Ridgway chart).

No acid from carbohydrate media.

Indole not formed.

Nitrites not produced from nitrates.

Aerobic, facultative.

Optimum temperature 42°C.

Source: Isolated from cured codfish (Harrison and Kennedy, *loc. cit.*). Isolated from salted fish by Browne (Absts. Bact., *6*, 1922, 25 and Proc. Soc. Exper. Biol. and Med., *19*, 1922, 321) who regarded this pleomorphic bacterium as two organisms—*Spirochaeta halophilica* and *Bacterium halophilica*.

Habitat: Produces reddening of dried codfish and causes rusty herring. In sea salt, and salt ponds containing not less than 16 per cent salt.

61. **Pseudomonas cutirubra** Lochhead. (*Serratia cutirubra* Lochhead, Can. Jour. of Research, *10*, 1934, 275; *Bacterium cutirubrum* Lochhead, Jour. Bact., *27*, 1934, 62; *ibid.*, *45*, 1943, 575; *Flavobacterium (Halobacterium cutirubrum* Elazari-Volcani, *loc. cit.*, 59.) From Latin, *cutis*, skin, hide; *ruber*, red.

Occurs as rods and spheres. Spheres 1 to 1.5 microns in diameter. Rods 1.5 to 8.0 by 0.7–1.4 microns. Rod forms motile with single polar flagellum. Coccoid forms motile when young. Gram-negative.

No growth on ordinary media.

Milk agar (20 per cent salt to saturation; optimum 28–32 per cent): Colonies 3–4 mm. in diameter, round and slightly convex. Pink to rose dorée (Ridgway chart).

Milk agar slants: Growth filiform, slightly spreading, rather flat with smooth, glistening surface and membranous consistency. Proteolytic action.

Liquid media: No or slight growth.

Gelatin (salt): Pronounced liquefaction.

Indole not formed, Lochhead (*loc. cit.*), Faint test, Gibbons (Jour. Biol. Board Canada, *3*, 1936, 75).

Nitrites not produced from nitrates.

Diastatic action negative.

No carbohydrate fermentation.

Aerobic, obligate.

Optimum temperature 37°C.

Halophilic.

Source: Isolated from salted hides.

Habitat: Sea water and sea salt.

62. **Pseudomonas harveyi** Johnson *comb. nov.* (*Achromobacter harveyi* Johnson and Shunk, Jour. Bact., *31*, 1936, 587.) Named for E. N. Harvey, who studied luminous bacteria.

Rods: 0.5 to 1.0 by 1.2 to 2.5 microns, occurring singly or in pairs, with rounded ends. Occasionally slightly curved; ends occasionally slightly pointed. Non-spore-forming. Capsules absent. Motile with a single polar flagellum, 2 to 3 times the length of the cell. Gram-negative.

Sea water gelatin colonies: After 24 hours at 20°C, circular, about 1.5 mm. in diameter or larger, margin slightly undulate, sunken due to the beginning of liquefaction, interior somewhat zonate; colonies surrounded by a halo of numerous small secondary colonies, circular and finely granular. In crowded plates a large number of gas bubbles are formed. Luminescent.

Sea water gelatin stab: Rapid saccate liquefaction complete in 5 days at 22°C. Abundant flocculent sediment.

Sea water agar colonies: Mostly very large, 6 to 8 cm. in diameter in 24 hours, flat, highly iridescent, circular with undulate margin, or composed of narrow and close or wide filamentous growth. Occasionally small colonies appear that are circular, with entire or slightly undulate margin, often producing irregular secondary growth, surface always smooth. Luminescent.

Sea water agar slant: Growth abundant, spreading, grayishly viscous, homogeneous, iridescent, the medium becoming rapidly alkaline when inoculated at an initial pH of 7.0. With fish decoctions added to the medium, luminescence is much brighter and growth becomes brownish after several days.

Growth on autoclaved fish: Abundant, smooth, glistening, yellowish, becoming dirty brown after several days. Mild putrefactive odor. Luminescence very brilliant.

Sea water containing 0.2 per cent peptone: Abundant uniform turbidity, thin pellicle, sediment accumulating over a period of several days. Luminescence at surface only unless the tube is shaken.

Milk, with or without the addition of 2.8 per cent salt: No growth.

Potato plugs resting on cotton saturated with sea water: Growth slight, somewhat spreading, slightly brownish. Luminous.

Indole is formed (Gore's method).

Nitrites are produced from nitrates.

Ammonia is produced in peptone media (Hansen method).

Fixed acid from glucose, fructose, mannose, galactose, sucrose, maltose, mannitol, dextrin, glycogen, trehalose, cellobiose; slowly from salicin. Non-fixed acid from melezitose; slight acid from sorbitol, disappearing in 24 hours. No acid from glycerol, xylose, arabinose, dulcitol, inositol, adonitol, erythritol, arabitol, lactose, raffinose, rhamnose, fucose or alpha methyl glucoside.

Starch agar: Wide zone of hydrolysis.

Hydrogen sulfide is produced (Zobell and Fantham method).

Temperature relations: Optimum 35° to 39°C. Abundant growth at 22° to 25°C. Optimum luminescence at 20° to 40°C.

Not pathogenic for white rats or amphipods.

Aerobic, facultative anaerobe.

Source: Isolated from a dead amphipod (*Talorchestia sp.*) at Woods Hole, Massachusetts.

Habitat: Sea water.

63. **Pseudomonas phosphorescens** (Fischer) Bergey et al. (*Bacillus phosphorescens* Fischer, Zeitschr. f. Hyg., *2*, 1887, 58; *Photobacterium indicum* Beijerinck, Arch. Néerl. d. Sci. Exactes, *23*, 1889, 401; *Bacterium phosphorescens* Lehmann, Cent. f. Bakt., *5*, 1889, 785; not *Bacterium phosphorescens* Fischer, Cent. f. Bakt., *3*, 1888, 107; Bergey et al., Manual, 3rd ed., 1930, 177.) From Greek *phosphoreō*, to bear or bring light.

See page 699 for additional synonyms.

Description taken from Fischer (*loc. cit.*).

Small, thick rods: 2 to 3 times as long as wide, with rounded ends. Motile. Stain lightly with aniline dyes.

Gelatin colonies: After 36 hours, small, circular, gray-white, punctiform. Liquefaction. Bluish to green phosphorescence in 4 to 5 days.

Blood serum: Gray-white, slimy growth.

Potato: Thin white layer in 2 to 3 days.

Cooked fish: Abundant growth. Entire surface covered with a gray-white, slimy growth. Bluish-white phosphorescence.

Alkaline broth: Slight turbidity in 24 hours. Pellicle in 3 days.

Acid broth: No turbidity. No phosphorescence.

Milk: No growth.

No gas formed.

Not pathogenic for laboratory animals.

Aerobic.

Optimum temperature 20° to 30°C.

Source: From sea water of the West Indies.

Habitat: Sea water.

64. **Pseudomonas pierantonii** (Zirpolo) Bergey et al. (*Micrococcus pierantonii* Zirpolo, Boll. del. Societa dei Natural. in Napoli, *31*, 1918, 75; *Cocco-bacillus pierantonii* Meissner, Cent. f. Bakt., II Abt., *67*, 1926, 204; Bergey et al., Manual, 3rd ed., 1930, 176.) Named for Pierantoni, an Italian.

Oval rods: 0.8 by 1.0 to 2.0 microns. Polymorphic rods, sometimes vacuolated. Motile. Gram-negative.

Gelatin colonies: Circular, luminous.

Gelatin stab: Not liquefied.

Sepia agar colonies: Circular, white, convex, smooth, serrate edge. Intense greenish luminescence.

Egg-glycerol agar slant: Yellowish-green, luminous streak.

Broth: Turbid.

Indole not formed.

Acid from glucose and maltose, some strains also produce acid from lactose and sucrose.

Best growth in alkaline media.

Aerobic.

Optimum temperature 33°C.

Source: Isolated from the photogenic organ of the cephalopod *Rondeletia minor*.

*65. **Pseudomonas martyniae** (Elliott) Stapp. (*Bacterium martyniae* Elliott, Jour. Agr. Res., *29*, 1924, 490; Stapp, in Sorauer, Handbuch der Pflanzenkr., *2*, 5 Auf., 1928, 278; *Phytomonas martyniae* Bergey et al., Manual, 3rd ed., 1930, 262.) From M. L. *Martynia*, a generic name.

Rods: 0.59 to 1.68 microns. Capsules. Chains. Motile with one to several bipolar flagella. Gram-negative.

Green fluorescent pigment produced.

Gelatin: Liquefied.

Beef agar colonies: White, round, smooth, glistening, raised.

Broth: Clouding in bands. Thin pellicle. Small crystals.

Milk: Soft acid curd with peptonization.

Nitrites produced from nitrates after 2 weeks.

Indole not produced.

Hydrogen sulfide production slight.

Acid but not gas from glucose, galactose, arabinose and sucrose. No acid from rhamnose, lactose, maltose, raffinose, mannitol and glycerol.

Starch hydrolysis none or feeble.

Optimum temperature 26°C. Maximum 37°C. Minimum 1.5°C.

Optimum pH 6.0 to 6.7. pH range 5.4 to 8.9.

Aerobic.

Source: Isolated from diseased leaves of the unicorn plant from Kansas.

Habitat: Pathogenic on *Martynia louisiana*.

66. **Pseudomonas striafaciens** (Elliott) Burkholder. (*Bacterium striafaciens* Elliott, Jour. Agr. Res., *35*, 1927, 823; *Phytomonas striafaciens* Bergey et al., Manual, 3rd ed., 1930, 268; Burkholder, Phytopath., *32*, 1942, 601.) From L. *stria*, stripe; *faciens*, making,

* The section covering the pseudomonads that cause plant diseases has been revised by Prof. Walter H. Burkholder, Cornell Univ., Ithaca, New York, April, 1943.

referring to the type of lesion caused on the blades of oats.

Rods: 0.66 by 1.76 microns. Motile with one to several flagella. Capsules. Gram-negative.

Green fluorescent pigment produced.

Gelatin: Liquefied.

Beef-peptone agar colonies: White, raised, margins entire or slightly undulating.

Broth: Clouding in layers. Ring and slight pellicle.

Milk: Alkaline, sometimes a soft curd which digests or clears.

Slight production of nitrites from nitrates.

Indole not produced.

Acid but not gas from glucose, fructose and sucrose. No acid from lactose, maltose, glycerol and mannitol.

Starch: Hydrolysis slight.

Optimum temperature 22°C.

Optimum pH 6.5 to 7.0.

Aerobic.

Distinctive characters: Differs from *Pseudomonas coronafaciens* in that the cells are somewhat smaller and the pathogen produces a streak on oat blades instead of a halo spot.

Source: Forty cultures isolated from oats gathered in various parts of America.

Habitat: Pathogenic on cultivated oats, and to a slight degree, on barley.

67. **Pseudomonas tomato** (Okabe) *comb. nov.* (*Bacterium tomato* Okabe, Jour. Soc. Trop. Agr. Formosa, *5*, 1933, 32; *Phytomonas tomato* Magrou, in Hauduroy et al., Dict. d. Bact. Path., Paris, 1937, 422.) Named for the host plant, tomato.

Probable synonym: *Bacterium punctulans* Bryan, Phytopath., *23*, 1933, 897.

Rods: 0.69 to 0.97 by 1.8 to 6.8 microns. Motile with 1 to 3 polar flagella. Gram-negative.

Green fluorescent pigment produced in culture.

Gelatin: Slow liquefaction.

Beef-extract agar colonies: White, circular, flat and glistening.

Broth: Turbid in 24 hours. Pellicle.

Milk: Becomes alkaline and clears.

Nitrites are usually produced from nitrates.

Indole not produced.

No H_2S produced.

Acid but not gas from glucose, sucrose and lactose. No acid from maltose and glycerol.

Starch hydrolysis feeble.

Slight growth in 3 per cent salt.

Optimum temperature 20° to 25°C. Maximum 33°C.

Aerobic.

Source: Isolated from diseased tomato leaves.

Habitat: Pathogenic on tomato, *Lycopersicon esculentum*.

68. **Pseudomonas aceris** (Ark) Burkholder. (*Phytomonas aceris* Ark, Phytopath., *29*, 1939, 969; Burkholder, Phytopath., *32*, 1942, 601.) From Latin *acer*, maple; M.L. *Acer*, generic name.

Rods: 0.3 to 0.8 by 0.8 to 2.5 microns. Motile with 1 to 2 polar flagella. Gram-negative.

Green fluorescent pigment produced.

Gelatin: Liquified.

Beef-extract-peptone agar: Colonies are grayish-white. Appearing in 24 hours.

Broth: Turbid.

Milk: Clearing with no coagulation.

Nitrites not produced from nitrates.

Indole not produced.

Hydrogen sulfide not produced.

Acid from glucose, fructose, galactose, arabinose, xylose, sucrose, maltose, lactose, raffinose, mannitol, glycerol and dulcitol.

Slight growth in broth plus 6 per cent salt (Burkholder).

Temperature: 13° to 31°C.

Source: From diseased leaves of the large leaf maple, *Acer macrophillum*.

Habitat: Causes a disease of *Acer spp.*

69. **Pseudomonas angulata** (Fromme and Murray) Holland. (*Bacterium angulatum* Fromme and Murray, Jour. Agr. Res., *16*, 1919, 219; Holland, Jour. Bact., *5*, 1920, 224; *Phytomonas angulata* Bergey

et al., Manual, 3rd ed., 1930, 267.) From L. *angulatus*, referring to the type of lesion produced on the tobacco leaf.

Description taken from Clara (Cornell Agr. Exp. Sta. Mem. 159, 1934, 24).

Rods: 0.75 to 1.5 by 1.5 to 3.0 microns. Motile by 1 to 6 polar flagella. Gram-negative.

Gelatin: Liquefaction.

Green fluorescent pigment produced.

Beef-extract agar colonies: Dull white, circular, raised, smooth and glistening.

Broth: Turbid in 36 hours and greenish.

Milk: Alkaline.

Nitrites not produced from nitrates.

Indole not produced.

No H_2S produced.

Lipolytic action negative (Starr and Burkholder, Phytopath., *32*, 1942, 601).

Acid but not gas from glucose, galactose, fructose, mannose, arabinose, xylose, sucrose and mannitol. Alkaline reaction from salts of citric, malic, succinic and tartaric acid. Rhamnose, maltose, lactose, raffinose, glycerol, salicin, and acetic, lactic and formic acids are not fermented.

Starch not hydrolyzed.

Slight growth in broth plus 5 to 6 per cent salt (Burkholder).

Facultative anaerobe.

Distinctive characters: Braun (Phytopath., *27*, 1937, 283) considers this species to be identical in culture with *Pseudomonas tabaci*, but they differ in the type of disease they produce.

Sources: Isolated by Fromme and Murray from small angular leaf spots on tobacco.

Habitat: Causes the angular leaf spot of tobacco (*Nicotiana tabacum*).

70. **Pseudomonas aptata** (Brown and Jamieson) Stevens. (*Bacterium aptatum* Brown and Jamieson, Jour. Agr. Res., *1*, 1913, 206; *Phytomonas aptata* Bergey et al., Manual, 1st ed., 1923, 184; Stevens, Plant Disease Fungi, New York, 1925, 22.) From Latin *aptatus* adapted.

Rods: 0.6 to 1.2 microns. Motile with bipolar flagella. Gram-negative.

Green fluorescent pigment produced in culture.

Gelatin: Liquefaction.

Agar slants: Moderate growth along streak, filiform, whitish, glistening.

Broth: Turbid: A pellicle formed.

Milk: Becomes alkaline and clears.

Nitrites not produced from nitrates.

Indole not produced in 10 days. Slight amount found later.

No H_2S produced.

Acid from glucose, galactose and sucrose. No acid from lactose, maltose and mannitol (Paine and Banfoot, Ann. Appl. Biol., *11*, 1924, 312).

Starch not hydrolyzed.

Slight growth in broth plus 7 per cent salt (Burkholder).

Optimum temperature 27° to 28°C. Maximum 34° to 35°C. Minimum below 1°C.

Aerobic.

Source: Isolated from diseased nasturtium leaves from Virginia and diseased beet leaves from Utah.

Habitat: Pathogenic on sugar beets, nasturtiums, and lettuce.

71. **Pseudomonas primulae** (Ark and Gardner) Starr and Burkholder. (*Phytomonas primulae* Ark and Gardner, Phytopath., *26*, 1936, 1053; Starr and Burkholder, Phytopath., *32*, 1942, 601.) From L. *primulus*, first; M.L. *Primula*, a generic name.

Rods: 0.51 to 0.73 by 1.0 to 3.16 microns. Motile with a polar flagellum. Gram-negative.

Green fluorescent pigment produced in culture.

Gelatin: Liquefaction.

Agar colonies: Round, convex, smooth, glistening, yellowish.

Milk: Coagulated.

Nitrites not produced from nitrates.

Indole not produced. No H_2S produced.

Not lipolytic (Starr and Burkholder, Phytopath., *32*, 1942, 601).

Acid but not gas from glucose, lactose, sucrose, maltose, galactose, arabinose,

glycerol, dulcitol and mannitol. Starch not hydrolyzed.

Growth in broth plus 5 per cent salt.

Optimum temperature 19° to 22°C. Maximum 34°C. Minimum 10°C.

Optimum pH 6.8 to 7.0. Minimum 4.5 to 5.0.

Facultative anaerobe.

Source: Isolated from leaf-spot of *Primula polyantha*.

Habitat: Pathogenic on *Primula spp.*

72. **Pseudomonas viridilivida** (Brown) Holland. (*Bacterium viridilividum* Brown, Jour. Agr. Res., *4*, 1915, 475; Holland, Jour. Bact., *5*, 1920, 225; *Phytomonas viridilivida* Bergey et al., Manual, 1st ed., 1923, 187.) From Latin, *viridis*, green; *lividus*, blue.

Rods: 1.0 to 1.25 by 1.25 to 3.0 microns. Motile with 1 to 3 polar flagella. Gram-negative.

Green fluorescent pigment produced in culture.

Gelatin: Slow liquefaction.

Beef agar colonies: Cream white, round, smooth, translucent, edges entire.

Broth: Turbid, becomes lime green.

Milk: Alkaline and clears.

Nitrites not produced from nitrates.

Indole is produced.

Not lipolytic (Starr and Burkholder, Phytopath., *32*, 1942, 601).

Acid from glucose and sucrose (Burkholder).

Grows well in 4.5 per cent salt. Grows in 7 per cent salt (Burkholder).

Maximum temperature 34.5°C. Minimum 1.5°C.

Aerobic.

Source: Isolated from diseased lettuce from Louisiana.

Habitat: Pathogenic on lettuce, *Lactuca sativa*.

73. **Pseudomonas delphinii** (Smith) Stapp. (*Bacillus delphini* Smith, Science, *19*, 1904, 417; *Bacterium delphinii* Bryan, Jour. Agr. Res., *28*, 1924, 261; Stapp, in Sorauer, Handbuch der Pflanzenkrankheiten, *2*, 5 Auf., 1928, 106; *Phytomonas delphinii* Bergey et al., Manual, 3rd ed., 1930, 261.) From Latin, *delphin*, a dolphin; M.L. *Delphinium*, a generic name.

Rods: 0.6 to 0.8 by 1.5 to 2.0 microns. Chains present. Motile with 1 to 6 polar flagella. Capsules. Gram-negative.

Green fluorescent pigment produced in culture.

Gelatin: Liquified.

Beef agar slants: Growth thin, smooth, shining, transparent, margins entire, crystals. Agar becomes dark brown.

Broth: Turbid in 24 hours with delicate pellicle.

Milk: Becomes alkaline and clears.

Nitrites not produced from nitrates.

Indole not produced.

No H_2S produced.

Lipolytic action negative (Starr and Burkholder, Phytopath., *32*, 1942, 601).

Acid from glucose, galactose and fructose; slightly acid from sucrose. No acid from lactose, maltose, glycerol and mannitol.

Starch: Hydrolysis feeble.

Weak growth in broth plus 4 per cent salt.

Optimum pH 6.7 to 7.1. pH range 5.6 to 8.6.

Optimum temperature 25°C. Maximum 30°C. Minimum 1°C. or less.

Source: Isolated from black spot of delphinium.

Habitat: Pathogenic on delphinium causing a black spot in the leaves.

74. **Pseudomonas berberidis** (Thornberry and Anderson) Stapp. (*Phytomonas berberidis* Thornberry and Anderson, Jour. Agr. Res., *43*, 1931, 36; Stapp, Bot. Rev., *1*, 1935, 407; *Bacterium berberidis* Burgwitz, Phytopathogenic Bacteria, Leningrad, 1935, 153.) From M.L. *Berberis*, barberry, generic name.

Rods: 0.5 to 1.0 by 1.5 to 2.5 microns, occurring singly or in pairs. Motile with 2 to 4 polar flagella. Capsules present.

Gram-negative (Burkholder); not Gram-positive as stated in original description.

Green fluorescent pigment produced in culture (Burkholder).

Gelatin: Not liquefied.

Glucose agar slants: Growth moderate, filiform at first, later beaded, raised, smooth, white. Butyrous in consistency.

Milk: Becomes alkaline. No other change.

Nitrites not produced from nitrates.

Indole not produced.

No H_2S produced.

Not lipolytic (Starr and Burkholder, Phytopath., *32*, 1942, 601).

Acid from glucose, galactose, and sucrose. Maltose and rhamnose not utilized (Burkholder).

No gas from carbohydrates.

Starch not hydrolyzed.

Optimum temperature 18°C. Maximum 30°C. Minimum 7°C.

Aerobic.

Sources: Repeated isolations from leaves and twigs of barberry.

Habitat: Pathogenic on barberry, *Berberis thunbergerii* and *B. vulgaris*.

75. Pseudomonas coronafaciens (Elliott) Stapp. (*Bacterium coronafaciens* Elliott, Jour. Agr. Res., *19*, 1920, 153; *Phytomonas coronafaciens* Bergey et al., Manual, 1st ed., 1923, 180; Stapp, in Sorauer, Handbuch der Pflanzenkrankheiten, *2*, 5 Auf., 1928, 20.) From L. *corona*, halo; *faciens*, producing, referring to the lesions on oat blades.

Probable synonyms: Elliott (Bact. Plant Pathogens, 1930, 122) lists as synonyms, *Bacillus avenae* (Russell, Johns Hopkins Univ. Thesis, 1892) and *Bacillus avenae* Manns and *Pseudomonas avenae* Manns (Ohio Agr. Exp. Sta. Bul. 210, 1909, 133; *Phytomonas avenae* Bergey et al., Manual, 3rd ed., 1930, 263).

Rods: 0.65 by 2.3 microns, occurring in chains. Motile with polar flagella. Capsules. Gram-negative.

Green fluorescent pigment produced in culture.

Gelatin: Slow liquefaction.

Nutrient agar colonies: White, becoming irregularly circular, flat with raised margins.

Broth: Slight turbidity in 24 hours. Heavy pellicle formed.

Milk: Alkaline. A soft curd formed followed by clearing. Curd sometimes absent.

Nitrites not produced from nitrates.

Indole not formed.

No H_2S formed.

Not lipolytic (Starr and Burkholder, Phytopath., *32*, 1942, 601).

Acid but no gas from glucose and sucrose. Starch hydrolysis slight.

Slight growth in broth plus 2 per cent salt.

Optimum temperature 24° to 25°C. Maximum 31°C. Minimum 1°C.

Source: Numerous isolations from blighted blades of oats.

Habitat: Causes a halo spot on oats (*Avena sativa*). Artificial inoculations show barley (*Hordeum vulgare*), rye (*Secale cereale*) and wheat (*Triticum aestivum*) to be susceptible.

75a. *Pseudomonas coronafaciens* var. *atropurpurea* (Reddy and Godkin) Stapp. (*Bacterium coronafaciens* var. *atropurpureum* Reddy and Godkin, Phytopath., *13*, 1923, 81; Stapp, in Sorauer, Handbuch der Pflanzenkrankheiten, *2*, 5 Auf., 1928, 39; *Phytomonas coronafaciens* var. *atropurpurea* Magrou, in Hauduroy et al., Dict. d. Bact. Path., Paris, 1937, 371.) From L. *ater*, black, dark; *purpureus*, purple, referring to the color of the lesion on brome grass.

Distinctive characters: This variety differs from *Pseudomonas coronafaciens* in that it infects the brome-grass, *Bromus inermis*, where it produces a water soaked spot which is dark purple in color.

Source: Numerous isolations from diseased brome-grass.

Habitat: Pathogenic on *Bromus inermis* and *Agropyron repens*. Has been artificially inoculated on oats, *Avena sativa*.

76. **Pseudomonas lachrymans** (Smith and Bryan) Carsner. (*Bacterium lachrymans* Smith and Bryan, Jour. Agr. Res., *5*, 1915, 466; Carsner, Jour. Agr. Res., *15*, 1918, 15; *Bacillus lachrymans* Holland, Jour. Bact., *5*, 1920, 218; *Phytomonas lachrymans* Bergey et al., Manual, 1st ed., 1923, 184.) From Latin, causing tears, probably referring to the opaque drops formed on the lesion caused by this pathogen.

Synonym: Elliott (Man. Bact. Plant Pathogens, 1930, 147) lists the following as a synonym: *Bacillus burgeri* Potebnia, Khartov Prov. Agr. Exp. Sta., *1*, 1915, 37.

Description from Smith and Bryan (*loc. cit.*) and Clara (Cornell Agr. Exp. Sta. Mem. 159, 1934, 26).

Rods: 0.8 by 1 to 2 microns. Motile with 1 to 5 polar flagella. Capsules. Gram-negative.

Green fluorescent pigment produced in culture.

Gelatin: Liquefied.

Beef-peptone agar colonies: Circular, smooth, glistening, transparent, whitish, entire margins.

Broth: Turbid in 24 hours. White precipitate with crystals.

Milk: Turns alkaline and clears.

Nitrites not produced from nitrates.

Indole reaction weak.

No H_2S produced.

Not lipolytic (Starr and Burkholder, Phytopath., *32*, 1942, 601).

Acid but not gas from glucose, fructose, mannose, arabinose, xylose, sucrose and mannitol. Alkaline reaction from salts of citric, malic and succinic acid. Maltose, rhamnose, lactose, raffinose, glycerol and salicin not fermented (Clara, *loc. cit.*).

Starch partially digested. Not digested (Clara, *loc. cit.*).

Growth in 3 per cent salt after 12 days. No growth in 4 per cent salt.

Optimum temperature 25° to 27°C. Maximum 35°C. Minimum 1°C.

Aerobic. Facultative anaerobe (Clara, *loc. cit.*).

Source: Isolated from diseased cucumber leaves collected in New York, Wisconsin, Indiana and in Ontario, Canada.

Habitat: Pathogenic on cucumber, *Cucumis sativus*, and related plants.

77. **Pseudomonas maculicola** (McCulloch) Stevens. (*Bacterium maculicolum* McCulloch, U. S. Dept. Agr., Bur. Plant Ind. Bul., *225*, 1911, 14; Stevens, The Fungi which cause Plant Diseases, 1913, 28; *Phytomonas maculicola* Bergey et al., Manual, 1st ed., 1923, 189; *Bacterium macculIochianum* Burgwitz, Phytopathogenic Bacteria, Leningrad, 1935, 77.) From L. *maculus*, spot; *-cola*, dweller.

Rods: 0.9 by 1.5 to 3 microns. Filaments present. Motile with 1 to 5 polar flagella. Gram-negative.

Green fluorescent pigment produced in culture.

Gelatin: Liquefied.

Beef-peptone agar colonies: Whitish, circular, shining, translucent, edges entire.

Broth: Turbid. No ring or pellicle.

Milk: Becomes alkaline and clears.

Nitrites not produced from nitrates.

Indole production feeble.

No H_2S formed.

Not lipolytic (Starr and Burkholder, Phytopath., *32*, 1942, 601).

Acid from glucose, galactose, xylose, sucrose, glycerol, and mannitol. Alkaline reaction from salts of citric, malic, malonic, and succinic acid. Salicin, maltose, and salts of hippuric and tartaric not utilized (Burkholder).

Slight growth in broth plus 4 per cent salt (Erw. Smith, Bact. Plant Diseases, 1920, 306).

Aerobic.

Optimum temperature 24° to 25°C. Maximum 29°C. Minimum 0°C.

Source: Isolated from diseased cauliflower leaves from Virginia.

Habitat: Pathogenic on cauliflower and cabbage.

Note: *Bacterium maculicola* var. *japonicum* Takimoto, Bul. Sci. Fak. Terkult

Kjusu Imp. Univ., *4*, 1931, 545 has not been seen.

78. **Pseudomonas marginata** (McCulloch) Stapp. (*Bacterium marginatum* McCulloch, Science, *54*, 1921, 115; Jour. Agr. Res., *29*, 1924, 174; *Phytomonas marginata* Bergey et al., Manual, 1st ed., 1923, 188; Stapp, in Sorauer, Handbuch der Pflanzenkrankheiten, *2*, 5 Auf., 1928, 56.) From L. *marginatus*, having a border, probably refers to the definite margin of the colony.

Rods: 0.5 to 0.6 by 0.8 to 1.8 microns. Motile with 1 to 4 bipolar flagella. Capsules. Gram-negative.

Green fluorescent pigment produced in Uschinsky's and Fermi's solutions.

Gelatin: Liquefied.

Agar colonies: White, circular, smooth, translucent, viscid, with definite margins at first thin but later thick and contoured. Surface wrinkled.

Milk: At first slightly acid, then alkaline. Casein digested.

Nitrites not produced from nitrates.

Indole production slight.

Hydrogen sulfide production slight.

Lipolytic (Starr and Burkholder, Phytopath., *32*, 1942, 601).

Acid but not gas from glucose, lactose, sucrose and glycerol.

Starch hydrolysis feeble.

Growth in 3.5 per cent salt. No growth in 4 per cent salt. pH range, 4.6 to 9.1.

Optimum temperature 30° to 32°C. Maximum 40°C. Minimum 8° to 9°C.

Source: Repeatedly isolated from diseased gladiolus.

Habitat: Pathogenic on *Gladiolus spp.* and *Iris spp.*

79. **Pseudomonas medicaginis** Sackett. (Sackett, Science, *31*, 1910, 553; also Colorado Agr. Exp. Sta., Bull. 158, 1910, 11; *Bacillus medicaginis* Holland, Jour. Bact., *5*, 1920, 219; *Phytomonas medicaginis* Bergey et al., Manual, 1st ed., 1923, 179; *Bacterium medicaginis* Elliott, Bact. Plant Path., 1930, 162.) From L. *medica*, ancient Media; M.L. *Medicago*, a generic name.

Rods: 0.7 by 1.2 microns. Motile with 1 to 4 flagella. Filaments present. Gram-negative.

Green fluorescent pigment produced in culture.

Gelatin: Not liquefied.

Nutrient agar colonies: Growth in 24 hours whitish, glistening.

Broth: Turbid in 24 hours. Pellicle formed. Viscid sediment.

Milk: Becomes alkaline. No change.

Nitrites not produced from nitrates.

Indole not produced.

No H_2S produced.

Not lipolytic (Starr and Burkholder, Phytopath., *32*, 1942, 601).

Starch not hydrolyzed.

No gas from carbohydrates. Acid from sucrose.

Slight growth in broth plus 3.75 per cent salt.

Optimum temperature 28° to 30°. Maximum 37.5°C.

Aerobic.

Source: Isolated from brown lesions on leaves and stems of alfalfa.

Habitat: Pathogenic on alfalfa, *Medicago sp.*

79a. **Pseudomonas phaseolicola** (Burkholder) Dowson. (*Phytomonas medicaginis* var. *phaseolicola* Burkholder, Phytopath., *16*, 1926, 915; *Bacterium medicaginis* var. *phaseolicola* Link and Hull, Bot. Gaz., *83*, 1927, 413; *Pseudomonas medicaginis* var. *phaseolicola* Stapp and Kotte, Nachrichtenb. f. d. Deutschen Pflanzenschutzdienst, *9*, 1929, 35; Dowson, Brit. Mycol. Soc. Trans., *26*, 1943, 10.) From L. *phaseolus*, bean; M.L. *Phaseolus*, a generic name;-*cola*, dweller.

Synonym: *Bacterium puerariae* Hedges. (Phytopath., *17*, 1927, 48 and *20*, 1930, 140; *Phytomonas puerariae* Bergey et al., Manual, 3rd ed., 1930, 267.)

Description from Burkholder and Zaleski (Phytopath., *22*, 1932, 85).

Rods: 1 by 2 microns, sometimes slightly curved, filaments present. Motile with polar flagellum. Gram-negative.

Green fluorescent pigment produced in culture.

Gelatin stab: Slow liquefaction.

Beef extract agar: Whitish, circular colonies, 2 mm. in diameter. Edges entire.

Broth: Turbid.

Milk: Alkaline.

Nitrites not produced from nitrates.

Indole not formed.

Hydrogen sulfide not formed.

Not lipolytic (Starr and Burkholder, Photopath., *32*, 1942, 601).

Acid but no gas from glucose, fructose, mannose, arabinose, xylose, sucrose and glycerol. No acid from rhamnose, lactose, maltose, mannitol and salicin. Alkali from salts of citric and malic acids, but not from acetic, formic, lactic or tartaric acids. Starch and cellulose not hydrolyzed.

Slight growth in broth plus 4 per cent salt.

Optimum temperature 20° to 23°C. Maximum 33°C. Minimum 2.5°C. (Hedges, *loc. cit.*).

Optimum pH 6.7 to 7.3. Maximum 8.8 to 9.2. Minimum 5.0 to 5.3. (Kotte, Phyt. Zeitsch., *2*, 1930, 453.)

Microaerophilic.

Source: Isolated from leaves, pod and stem of beans showing halo blight.

Habitat: Pathogenic on beans (*Phaseolus vulgaris*), the kudzu vine (*Pueraria hirsuta*) and related plants.

80. **Pseudomonas pisi** Sackett. (Sackett, Colorado Agr. Exp. Sta., Bull. 218, 1916, 19; *Bacterium pisi* Erw. Smith, An Introduction to Bacterial Diseases of Plants, 1920, 474; *Phytomonas pisi* Bergey et al., Manual, 1st ed., 1923, 181.) From Gr. *pisum*, the pea; M.L. *Pisum*, a generic name.

Rods: 0.68 to 2.26 microns. Motile with a polar flagellum. Gram-negative.

Green fluorescent pigment produced in culture.

Gelatin: Liquefaction.

Agar slants: Moderate growth in 24 hours, filiform, glistening, grayish-white.

Broth: Turbid with a scum in 5 days.

Milk: Alkaline, soft curd, clears.

Nitrites not produced from nitrates.

Indole not produced.

No H_2S produced.

Not lipolytic (Starr and Burkholder, Phytopath., *32*, 1942, 601).

Acid but not gas from glucose, galactose and sucrose.

Starch not hydrolyzed.

Optimum temperature 27° to 28°C. Maximum 37.5°C. Minimum 7°C.

Aerobic.

Source: Ten cultures isolated from 5 collections of diseased peas showing water soaked lesions on stems and petioles.

Habitat: Pathogenic on garden peas, *Pisum sativum* and field peas, *P. sativum* var. *arvense*.

81. **Pseudomonas syringae** van Hall. (Kennis der Bakter. Pflanzenziekte, Inaug. Diss., Amsterdam, 1902, 191; *Bacterium syringae* Erw. Smith, Bacteria in Relation to Plant Diseases, *1*, 1905, 63; *Phytomonas syringae* Bergey et al., Manual, 3rd ed., 1930, 257.) From Latin, *syringa*, a nymph that was changed into a reed; M.L. *Syringa*, a generic name.

Synonyms: Bryan (Jour. Agr. Res., *36*, 1928, 225) lists *Bacterium citriputeale* C. O. Smith, Phytopath., *3*, 1913, 69, and *Bacterium citrarefaciens* Lee, Jour. Agr. Res., *9*, 1917, 1 (*Pseudomonas citrarefaciens* Stapp, in Sorauer, Handb. d. Pflanzenkrankheiten, *2*, 5 Aufl., 1928, 190). Clara (Cornell Agr. Exp. Sta. Mem. 159, 1934, 29) lists *Bacterium vignae* (*Pseudomonas vignae*) Gardner and Kendrick, Science, *57*, 1923, 275 (*Phytomonas vignae* Bergey et al., Manual, 1st ed., 1923, 188), *Pseudomonas viridifaciens* Tisdale and Williamson, Jour. Agr. Res., *25*, 1923, 141 (*Bacterium viridifaciens* Tisdale and Williams, *ibid.*; *Phytomonas*

viridifaciens Bergey et al., Manual, 2nd ed., 1925, 208), and *Phytomonas vignae* var. *leguminophila* Burkholder, Cornell Agr. Exp. Sta. Mem. 127, 1930, 51. Wilson (Phytopath., *30*, 1940, 27) lists *Phytomonas cerasi* (Griffin) Bergey et al. (*Pseudomonas cerasus* Griffin, Science, *34*, 1911, 615; *Bacillus cerasus* Holland, Jour. Bact., *5*, 1920, 217; Bergey et al., Manual, 3rd ed., 1930, 262; *Bacterium cerasi* Elliott, Bact. Plant Pathogens, 1930, 109.) This would include, therefore the following synonyms which have been listed for *Phytomonas cerasi*. Clara (Cornell Agr. Exp. Sta. Mem. 159, 1934, 25) lists *Bacterium trifoliorum* Jones et al. (Jour. Agr. Res., *25*, 1923, 471; *Phytomonas trifoliorum* Burkholder, Phytopath., *16*, 1926, 922; *Pseudomonas trifoliorum* Stapp, in Sorauer, Handb. d. Pflanzenkrankheiten, *2*, 5 Aufl., 1928, 177) and *Bacterium holci* Kendrick (Phytopath., *16*, 1926, 236; *Pseudomonas holci* Kendrick, *ibid.*; *Phytomonas holci* Bergey et al., Manual, 3rd ed., 1930, 258). Wilson (Hilgardia, *10*, 1936, 213) lists *Pseudomonas prunicola* Wormald (Ann. Appl. Biol., *17*, 1930, 725), *Pseudomonas cerasi* var. *prunicola* Wilson (Hilgardia, *8*, 1933, 83), *Bacterium citriputeale* C. O. Smith (Phytopath., *4*, 1913, 69; *Pseudomonas citriputealis* Stapp, in Sorauer, Handb. d. Pflanzenkrankheiten, *2*, 5 Aufl., 1928, 190; *Phytomonas citriputealis* Bergey et al., Manual, 3rd ed., 1930, 278) and *Pseudomonas utiformica* Clara, Science, *75*, 1932, 111 (*Phytomonas utiformica* Clara, Cornell Agr. Exp. Sta. Mem. 159, 1934, 29; *Bacterium utiformica* Burgwitz, Phytopathogenic Bacteria, Leningrad, 1935, 444). A probable synonym is *Phytomonas spongiosa* (Aderhold and Ruhland) Magrou (*Bacillus spongiosus* Aderhold and Ruhland, Cent. f. Bakt., II Abt., *15*, 1905, 376; *Pseudomonas spongiosa* Braun, Die Landwirtschaft, 41, 42, 1927, 2 pp.; *Bacterium spongiosum* Elliott, Man. Bact. Plant Pathogens, 1930, 214; Magrou, in Hauduroy et al., Dict. d. Bact. Path., Paris, 1937, 414). C. O. Smith (Phytopath., *33*, 1943, 82) lists the following as a synonym: *Pseudomonas hibisci* (Nakata and Takimoto) Stapp (*Bacterium hibisci* Nakata and Takimoto, Ann. Phytopath. Soc. Japan, *1*, 5, 1923, 18; Stapp, in Sorauer, Handbuch der Pflanzenkrankheiten, 5 Aufl., *2*, 1928, 203; *Phytomonas hibisci* Bergey et al., Manuals 3rd ed., 1930, 264).

Description from Clara (*loc. cit.*).

Rods: 0.75 to 1.5 by 1.5 to 3.0 microns. Motile with 1 or 2 polar flagella. Gram-negative.

Green fluorescent pigment produced in culture.

Gelatin: Liquefaction.

Beef-extract agar colonies: Circular, grayish-white with bluish tinge. Surface smooth. Edges entire or irregular.

Broth: Turbid in 36 hours. No pellicle.

Milk: Alkaline.

Nitrites not produced from nitrates.

Indole not produced.

No H_2S produced.

Not lipolytic (Starr and Burkholder, Phytopath., *32*, 1942, 601).

Slight growth in broth plus 4 per cent salt.

Acid but not gas from glucose, galactose, mannose, arabinose, xylose, sucrose, mannitol and glycerol. Alkaline reaction from salts of citric, malic, succinic and lactic acid. Rhamnose, maltose, lactose, raffinose, salicin, and acetic, formic and tartaric acid not fermented.

Starch not hydrolyzed.

Facultative anaerobe.

Source: Van Hall originally isolated the pathogen from lilac.

Habitat: Pathogenic on lilac, citrus, cow peas, beans, lemons, cherries and many unrelated plants.

81a. Orsini reports the following as a variety—*Bacterium syringae* var. *capsici* Orsini. (Intern. Bull. Plant Prot., *33*, 1942, 33.) Pathogenic on the pepper plant (*Capsicum*).

82. **Pseudomonas atrofaciens (McCulloch) Stevens.** (*Bacterium atrofaciens*

McCulloch, Jour. Agr. Res., *18*, 1920, 549; *Phytomonas atrofaciens* Bergey et al., Manual, 1st ed., 1923, 185; Stevens, Plant Disease Fungi, New York, 1925, 22.) From Latin, *ater*, black; *faciens*, making, referring to the color of the lesion on wheat.

Rods: 0.6 by 1 to 2.7 microns. Long chains formed in culture. Capsules present. Motile with 1 to 4 polar or bipolar flagella. Gram-negative.

Green fluorescent pigment produced in culture.

Gelatin: Liquefied.

Beef-peptone-agar colonies: Circular, shining, translucent, white.

Broth: Growth never heavy, slight rim, and a delicate pellicle.

Milk: Becomes alkaline and clears.

Nitrites not produced from nitrates.

Indole: Slight production.

Hydrogen sulfide: Slight production.

Acid and no gas from glucose, galactose and sucrose.

Starch is slightly hydrolyzed.

Optimum temperature 25° to 28°C. Maximum 36° to 37°C and minimum below 2°C.

Aerobic.

Sources: Isolated from diseased wheat grains collected throughout United States and Canada.

Habitat: Causes a basal glume-rot of wheat.

83. **Pseudomonas cumini** (Kovacevski) Dowson. (*Phytomonas cumini* Kovacevski, Bull. Soc. Bot. Bulgarie, *7*, 1936, 27; Dowson, Trans. Brit. Mycol. Soc., *26*, 1943, 10.) From Greek *cuminum*, cumin; M.L. *Cuminum*, a generic name.

Rods: 0.5 to 0.7 by 1 to 3 microns, occurring in chains and filaments. Motile with 1 to 3 polar flagella. Gram-negative.

Green fluorescent pigment formed in culture.

Gelatin: Rapidly liquefied.

Potato agar colonies: Grayish-white, circular, glistening, smooth, butyrous.

Broth: Moderate turbidity. Pseudozoogloea.

Milk: Not coagulated. Casein peptonized.

Nitrites not produced from nitrates.

Indole not formed.

No H_2S formed.

Acid but not gas from glucose and sucrose. No acid from lactose or glycerol. Starch not hydrolyzed.

Temperature range 5°C to 31°C.

Aerobic.

Source: Isolated from blighted cumin (*Cuminum*).

Habitat: Pathogenic on cumin and dill.

84. **Pseudomonas desaiana** (Burkholder) *comb. nov.* (*B. pyocyaneus saccharum* Desai, Ind. Jour. Agr. Sci., *5*, 1935, 391; *Phytomomas desaiana* Burkholder, in Bergey et al., Manual, 5th ed., 1939, 174.) Named for Desai who first isolated the species.

Rods: 0.6 to 1.2 by 1.2 to 2.2 microns. Motile with a polar flagellum. Gram-negative.

Green fluorescent pigment produced in culture.

Gelatin: Liquefaction.

Agar colonies: Grayish-blue. Raised.

Broth: Light clouding. Pellicle.

Milk: Peptonized without coagulation.

Nitrites not produced from nitrates.

Indole not formed.

Glucose, sucrose, lactose and glycerol fermented without gas.

Starch: Hydrolysis present.

Optimum temperature 30°C.

Aerobic.

Source: Isolated from stinking rot of sugar cane in India and associated with a white non-pathogenic bacterium.

Habitat: Pathogenic on sugar cane, *Saccharum officinarum*.

85. **Pseudomonas erodii** Lewis. (Phytopath., *4*, 1914, 231; *Bacterium erodii* Lewis, *ibid.*; *Phytomonas erodii* Bergey et al., Manual, 3rd ed., 1930, 256.) From Greek, *erodius*, heron; M.L. *Erodium*, a generic name.

Rods: 0.6 to 0.8 by 1.2 to 1.8 microns.

Motile with 1 to 3 polar flagella. Gram-negative.

Green fluorescent pigment produced in culture.

Gelatin: Liquefaction.

Agar stroke: Heavy, smooth, cream-colored growth in 24 hours.

Broth: Dense clouding in 24 hours.

Milk: Turns alkaline and clears, litmus reduced.

Nitrites not produced from nitrates.

Indole produced in 14 days.

No H_2S produced.

Acid but not gas from glucose, sucrose, lactose and glycerol.

Temperature: No growth at 35°C.

Aerobic, obligate.

Source: Isolations from *Erodium texanum* and 4 varieties of *Pelargonium*.

Habitat: Causes a leaf spot of *Erodium texanum* and *Pelargonium spp.*

86. **Pseudomonas apii** Jagger. (Jagger, Jour. Agr. Res., *21*, 1921, 186; *Phytomonas apii* Bergey et al., Manual, 1st ed., 1923, 184; *Pseudomonas jaggeri* Stapp, in Sorauer, Handbuch der Pflanzenkrankheiten, *2*, 5 Aufl., 1928, 210; *Bacterium jaggeri* Elliott, Bacterial Plant Pathogens, 1930, 142; *Phytomonas jaggeri* Magrou, in Handuroy et al., Dict. d. Bact. Path., Paris, 1937, 371.) From Latin, *apium*, parsley, M.L. *Apium*, a generic name.

Description from Clara (Cornell Agr. Exp. Sta. Mem. 159, 1934, 24).

Rods: 0.75 to 1.5 by 1.5 to 3.0 microns. Motile with a polar flagellum. Gram-negative.

Green fluorescent pigment produced in various media.

Gelatin: Liquefaction.

Beef-extract agar colonies: Circular, glistening, smooth, edges entire. Grayish-white with bluish tinge.

Broth: Turbid in 36 hours. Pellicle formed.

Milk: Becomes alkaline. No curd.

Nitrites not produced from nitrates.

Indole not formed.

No H_2S formed.

Acid but not gas from glucose, galactose, fructose, mannose, arabinose, xylose, sucrose, mannitol and glycerol. Alkaline reaction from salts of acetic, citric, malic and succinic acids. Rhamnose, maltose, lactose, raffinose, salicin, and formic, lactic and tartaric acid are not utilized.

Starch not hydrolyzed.

Facultative anaerobe.

Distinctive characters: Pathogenicity appears limited to celery.

Source: Jagger isolated this repeatedly from diseased celery leaves.

Habitat: Pathogenic on celery, *Apium graveolens*.

87. **Pseudomonas matthiolae** (Briosi and Pavarino) Dowson. (*Bacterium matthiolae* Briosi and Pavarino, Atti della Reale Accad. dei Lincei Rend., *21*, 1912, 216; *Phytomonas matthiolae*, Bergey et al., Manual, 3rd ed., 1930, 266; Mushin, Proc. Roy. Soc. Victoria, *53*, 1941, 201; Dowson, Trans. Brit. Mycol. Soc., *26*, 1943, 10.) From M.L. *Matthiola*, a generic name.

Rods: 0.4 to 0.6 by 2 to 4 microns. Gram-positive. Gram-negative (Mushin, *loc. cit.*).

Green fluorescent pigment produced in culture.

Gelatin: Liquefied.

Beef agar colonies: White, circular colonies, slightly elevated, margins smooth.

Broth: Slightly turbid. Becomes pale green.

Milk: Coagulation with acid react on.

Nitrites produced from nitrates (Mushin).

Hydrogen sulfide not formed.

Acid from glucose, galactose, fructose, mannose, rhamnose, glycerol, mannitol, acetic acid, citric acid, formic acid, lactic acid, malic acid, and succinic acid. Feeble acid in maltose. No acid: no gas in lactose, sucrose, raffinose, starch, salicin, and tartaric acid (Mushin).

Optimum temperature 20 to 24°C.

Maximum temperature 38.5 C. Minimum below 0°C. (Mushin).

Limits of growth in broth are pH 4.4 to pH 9.5 (Mushin).

Aerobic.

Source: Isolated from vascular and parenchymatic disease of stocks, *Matthiola incana* var. *annua*.

Habitat: Pathogenic on stocks.

NOTE: Burkholder (Phytopath., *28*, 1938, 936) and Santarelli (Rev. di Pat. Veg., *29*, 1939, 364) consider this species a synonym of *Pseudomonas syringae*. Adam and Pugsley (Jour. Dept. Agric. Victoria, *32*, 1934, 306) give a description of a green fluorescent pathogen on stocks which is similar to *Pseudomonas syringae*. Mushin (*loc. cit.*) considers *Pseudomonas matthiolae* to be a distinct species.

88. **Pseudomonas mors-prunorum** Wormald. (Jour. Pom. and Hort. Sci., *9*, 1931, 251; *Phytomonas mors-prunorum* Wormald, Trans. Brit. Mycol. Soc., *17*, 1932, 169; *Bacterium mors-prunorum*, *ibid.*) From L. *mors*, death; *prunus*, plums.

Rods: Motile with a polar flagellum. Gram-positive (1931). Gram-negative (1932).

Note: Possibly a green fluorescent organism since it produces a faint yellow color in Uschinsky's solution.

Gelatin: Liquefaction.

Agar colonies: White.

Broth plus 5 per cent sucrose: White and cloudy.

Nitrites not produced from nitrates.

Acid but not gas from glucose, lactose, sucrose and glycerol.

Starch not hydrolyzed.

Strict aerobe.

Distinctive characters: Differs from *Pseudomonas prunicola* (*Pseudomonas syringae*) in that it produces a white cloudy growth in broth plus 5 per cent sucrose; a rapid acid production in nutrient agar plus 5 per cent sucrose, and a faint yellow or no color in Uschinsky's solution.

Source: Isolated from cankers on plum trees in England.

Habitat: Pathogenic on *Prunus spp.*

89. **Pseudomonas rimaefaciens** Koning. (Chron. Bot., *4*, 1938, 11; Meded. Phytop. Labor, Willie Comm. Scholt., *14*, 1938, 24.) From L. *rima*, fissure; *faciens*, producing.

Rods: 0.6 to 2.4 microns in length. Motile with 1 to 3 polar flagella. Gram-negative.

Yellow-green fluorescent water-soluble pigment produced in culture.

Gelatin: Liquified.

Agar colonies: Round, convex, smooth, somewhat granular with hyaline edge.

Broth: Turbid. Surface growth with a sediment in a few days.

Milk: Alkaline and clears.

Nitrites not produced from nitrates. Peptone, asparagin, urea, gelatin, nitrates and ammonia salts are sources of nitrogen.

Hydrogen sulfide not produced.

Indole production slight.

Growth with the following carbon sources plus NO_3, glucose, sucrose, glycerol, succinates, malates, citrates and oxalates. Less growth with mannitol, fructose, galactose, lactose, salicylate. Acid is produced from the sugars. No growth with dextrin, inulin, maltose, lactose, rhamnose, salicin, tartrates, acetates, formates.

Starch not hydrolyzed.

Aerobic.

Optimum temperature 25°C. Maximum about 37°C. Very slow growth at 14°C. Thermal death point 42° to 48°C.

Source: Strains of the pathogen isoated from poplar cankers in France and in the Netherlands.

Habitat: Pathogenic on *Populus brabantica*, *P. trichocarpa* and *P. candicans*.

This may be *Pseudomonas syringae* since the characters are the same and both organisms can infect *Impatiens sp.* *Pseudomonas syringae* infects poplars (Elliott, Bacterial Plant Pathogens, 1930, 218).

90. **Pseudomonas papulans** Rose. (Rose, Phytopath., *7*, 1917, 198; *Phytomonas papulans* Bergey et al., Manual, 3rd ed., 1930, 267; *Bacterium papulans* Elliott, Bacterial Plant Pathogens, 1930, 175; *Phytomonas syringae* var. *papulans* Smith, Jour. Agr. Res., *68*, 1944, 294.) From L. *papulans*, forming blisters.

Rods: 0.6 by 0.9 to 2.3 microns. Motile with 1 to 6 polar flagella. Gram-negative.

Green fluorescent pigment produced in culture.

Gelatin: Liquefied.

Broth: Moderate turbidity in 24 hours.

Milk: Alkaline and at times a soft coagulum.

Nitrites not produced from nitrates.

Indole: May or may not be produced.

Acid but not gas formed from glucose and sucrose.

Optimum temperature 25° to 28°C. Maximum 37°C.

Source: Twenty-five cultures isolated from blisters on apples and from rough bark.

Habitat: Pathogenic on apple trees.

91. **Pseudomonas pseudozoogloeae** (Honing) Stapp. (*Bacterium pseudozoogloeae* Honing, Bull. van Het. Deli Proefstation, Medan, *1*, 1914, 7; Stapp, in Sorauer, Handbuch der Pflanzenkrankheiten, *2*, 5 Auf., 1928, 274; *Phytomonas pseudozoogloeae* Bergey et al., 3rd ed., 1930, 261.) From Gr., *pseudo*, false; M. L. *zoogloea*, zooglea.

Rods: 0.7 to 1.5 by 0.9 to 2.5 microns. Chains. Motile with 1 or 2 polar flagella. Gram-negative.

Green fluorescent pigment produced in culture.

Gelatin: Liquefaction.

Agar colonies: Round, flat, yellow-gray.

Broth: Moderate turbidity with pseudozoogloea in the pellicle.

Milk: Coagulation. No clearing.

Nitrites not produced from nitrates.

Indole not formed.

Hydrogen sulfide produced.

Acid but not gas from glucose, lactose, maltose, sucrose and mannitol.

Facultative anaerobe.

Source: Isolated from the black rust of tobacco.

Habitat: Pathogenic on tobacco, *Nicotiana tabacum*.

92. **Pseudomonas tabaci** (Wolf and Foster) Stevens. (*Bacterium tabacum* Wolf and Foster, Science, *46*, 1917, 362; also Jour. Agr. Res., *12*, 1918, 449; *Phytomonas tabaci* Bergey et al., Manual, 1st ed., 1923, 185; Stevens, Plant Disease Fungi, New York, 1925, 34.) From *Nicotiana tabacum*, tobacco.

Rods: 1.2 by 3.3 microns. Motile with a polar flagellum. Gram-negative.

Gelatin: Liquefaction.

Potato agar colonies: Grayish-white, circular, raised, wet-shining, smooth.

Milk: Alkaline; clears.

Nitrites not produced from nitrates.

Indole not formed.

Acid from glucose, galactose, fructose, l-arabinose, xylose, sucrose, pectin, mannitol and glycerol (Braun, Phytopath., *27*, 1937, 289).

Ammonium sulfate, potassium nitrate, cystine, glutamic acid, glycine, succinimide, oxamide, acetamide, and urea can be used as nitrogen source (Braun).

Starch not hydrolyzed. Aerobic.

Distinctive character: Braun (*loc. cit.*) states that *Pseudomonas tabaci* and *Pseudomonas angulata* are identical in culture.

Source: Isolated from wildfire lesions on tobacco leaves in North Carolina.

Habitat: Pathogenic on tobacco, *Nicotiana tabacum*.

93. **Pseudomonas lapsa** (Ark) Burkholder. (*Phytomonas lapsa* Ark, Phytopath., *30*, 1940, 1; Burkholder, *ibid.*, *32*, 1942, 601.) From Latin, *lapsus*, falling, referring to a symptom of the disease.

Rods: 0.56 by 1.55 microns. Motile with 1 to 4 polar flagella.

Produces fluorescence in Uschinsky's Fermi's, and Cohn's solutions.

Gelatin: Liquefied (Burkholder).

Acid but no gas is produced from glucose, sucrose, maltose, lactose, glycerine, arabinose, xylose, galactose, raffinose and mannitol.

Slight growth in broth plus 5 per cent salt (Burkholder).

Source: Isolated from stalk rot of field corn in California; also from *Diabrotica* beetles.

Habitat: Pathogenic on corn and sugar cane.

NOTE: Like *Pseudomonas desiana*.

94. **Pseudomonas bowlesiae** (Lewis and Watson) Dowson. (*Phytomonas bowlesii* Lewis and Watson, Phytopath., *17*, 1927, 511; *Bacterium bowlesii* Elliott, Bacterial Plant Pathogens, 1930, 96; Dowson, Trans. Brit. Mycol. Soc., *26*, 1943, 9.) From M. L. *Bowlesia*, a generic name.

Rods: 0.5 to 0.7 by 1.2 to 1.6 microns, occurring singly, in pairs or in short chains. Motile with bipolar flagella. Gram-negative.

Green fluorescent pigment produced in culture.

Gelatin: Liquefied.

Agar slants: Yellowish, moist, glistening and viscid.

Broth: Uniform turbidity throughout. Heavy viscous sediment in old cultures.

Milk: Alkaline; coagulation, with a slow peptonization.

Nitrites are produced from nitrates.

Indole is produced.

Hydrogen sulfide is produced.

Acid from glucose, maltose and xylose. No acid from sucrose.

Optimum temperature 27°C. Maximum 37°C. Minimum —1°C.

Optimum pH 7.2. pH range 4.5 to 8.6. Aerobic.

Source: Isolated from diseased, water soaked spots of bowlesia.

Habitat: Pathogenic on *Bowlesia septentrionalis*.

95. **Pseudomonas intybi** (Swingle) Stapp. (*Phytomonas intybi* Swingle, Phytopath., *15*, 1925, 730; Stapp, in Sorauer, Handbuch der Pflanzenkrankheiten, *2*, 5 Auf., 1928, 291; *Bacterium intybi* Elliott, Bacterial Plant Pathogens, 1930, 142.) From Latin, *intibus*, endive.

Description from Stapp, Cent. f. Bakt., II Abt., *91*, 1935, 232.

Rods: 0.4 to 0.5 by 1.4 to 2.8 microns. Motile with one to several polar flagella. Gram-negative.

Green fluorescent pigment formed in culture.

Gelatin: Liquefaction.

Agar colonies: White, glistening, transparent.

Broth: Turbid with fragile pellicle, and good sediment.

Milk: Coagulated. Casein not peptonized.

Nitrites are produced from nitrates with the formation of gas.

Indole not formed.

Acid but not gas from arabinose, xylose and glucose. No acid from sucrose.

Optimum temperature 23° to 28°C. Maximum 40° to 42°C. Minimum 0°C.

Distinctive character: Differs from *Pseudomonas cichorii* in that it liquefies gelatin and produces nitrites from nitrates.

Source: Isolated from French endive, *Cichorium intybus* by Swingle, from *C. endiva* and lettuce, *Lactuca sativa* by Stapp.

Habitat: Pathogenic on endive and lettuce, causing a rot.

96. **Pseudomonas marginalis** (Brown) Stevens. (*Bacterium marginale* Brown, Jour. Agr. Res., *13*, 1918, 386; *Phytomonas marginalis* Bergey et al., Manual, 1st ed., 1923, 182; Stevens, Plant Disease Fungi, New York, 1925, 30.) From Latin, *margo* (*marginis*), edge, margin; M.L. *marginalis*, on the margin, a character of the disease.

Description from Brown (*loc. cit.*) and Clara (Cornell Agr. Exp. Sta. Mem. 159, 1934, 27).

Rods: Motile with 1 to 3 polar flagella. Gram-negative.

Green fluorescent pigment produced in culture.

Gelatin: Liquefaction.

Agar colonies: Cream-colored to yellowish.

Broth: Turbid, with pellicle.

Milk: Alkaline. Soft curd at times.

Nitrites are produced from nitrates. Not produced (Clara, *loc. cit.*).

Indole not produced.

No H_2S produced.

Acid but not gas from glucose, galactose, fructose, mannose, arabinose, xylose, rhamnose, mannitol and glycerol. Alkali from salts of acetic, citric, malic, formic, lactic, succinic and tartaric acid. Sucrose, maltose, lactose, raffinose and salicin not fermented (Clara, *loc. cit.*).

Starch hydrolysis feeble. None (Clara, *loc. cit.*).

Optimum temperature 25° to 26°C. Maximum 38°C. Minimum 0°C.

Aerobic.

Source: Isolated from marginal lesion on lettuce from Kansas.

Habitat: Pathogenic on lettuce and related plants.

97. **Pseudomonas setariae** (Okabe) *comb. nov.* (*Bacterium setariae* Okabe, Jour. Soc. Trop. Agr. Formosa, *6*, 1934, 63; *Phytomonas setariae* Burkholder, in Bergey, Manual, 5th ed., 1939, 183.) From L. *seta*, bristle; *-arius*, like; M. L. *Setaria*, a generic name.

Rods: 0.4 to 0.8 by 1.8 to 4.4 microns. Motile with a polar, seldom bipolar, flagellum. Gram-negative.

Yellowish water-soluble pigment produced in culture.

Gelatin: Slow liquefaction.

Beef-extract agar colonies: Circular, white, opalescent, smooth, glistening.

Broth: Turbid after 18 hours. Pellicle.

Milk: Alkaline; clears.

Nitrites are produced from nitrates.

Indole is produced.

No H_2S produced.

Acid but not gas from glucose, galactose and glycerol. No acid from lactose, maltose or sucrose.

Starch: Feeble hydrolysis.

Grows in 3 per cent salt.

Optimum temperature 31° to 34°C. Maximum 42°C.

Aerobic.

Source: Isolated from brown stripe of Italian millet.

Habitat: Pathogenic on Italian millet, *Setaria italica*.

98. **Pseudomonas polycolor** Clara. (Clara, Phytopath., *20*, 1930, 704; *Phytomonas polycolor* Clara, *ibid.*, *Bacterium polycolor* Burgwitz, Phytopathogenic Bacteria, Leningrad, 1935, 148.) From Gr. *poly*, many; L. *color*, color.

Note: Delacroix (Comp. rend. Acad. Sci., Paris, *137*, 1903, 454) describes *Bacillus aerogenosus* as being a tobacco pathogen. The organism described by Delacroix might be the same as *Pseudomonas polycolor*. Braun and Elrod (Jour. Bact., *43*, 1942, 40) are of the opinion that Clara's pathogen is *Pseudomonas aeruginosa*.

Description taken from Clara (Cornell Agr. Exp. Sta. Mem. 159, 1934, 28).

Rods: 0.75 to 1.2 by 1.05 to 3.0 microns. Motile with 1 or 2 polar flagella. Gram-negative.

Green fluorescent pigment produced in culture.

Gelatin: Liquefaction.

Beef-extract agar colonies: Grayish-white, circular, raised, thin transparent margins.

Broth: Turbid in 36 hours with thin pellicle.

Milk: Alkaline; no curd.

Nitrites not produced from nitrates.

Indole not produced.

No H_2S produced.

Lipolytic (Starr and Burkholder, Phytopath., *32*, 1942, 601).

Acid but not gas from glucose, galactose, fructose, mannose, arabinose, xylose, mannitol and glycerol. Alkaline reaction from salts of acetic, citric, malic,

lactic and formic acid. Rhamnose, sucrose, maltose, lactose, raffinose and salicin not fermented.

Starch not hydrolyzed.

Facultative anaerobe.

Good growth in broth plus 7 per cent salt.

Optimum temperature 25° to 30°C. Maximum 37° to 39°C.

Distinctive character: Differs from *Pseudomonas mellea* in type of lesion produced, does not digest starch, nor reduce nitrates and does not form acid from lactose nor sucrose. Pathogenic for laboratory animals (Elrod and Braun, Sci. *94*, 1941, 520).

Source: Repeatedly isolated from leaf spot of tobacco in the Philippines.

Habitat: Pathogenic on tobacco.

99. **Pseudomonas viridiflava** (Burkholder) Clara. (*Phytomonas viridiflava* Burkh., Cornell Agr. Exp. Sta. Mem. 127, 1930, 63; Clara, Science, *75*, 1934, 111; *Bacterium viridiflavum* Burgwitz, Phytopathogenic Bacteria, Leningrad, 1935, 127.) From Latin *viridis*, green; *flavus*, yellow.

Description from Clara (Cornell Agr. Exp. Sta. Mem. 139, 1934, 30).

Rods: 0.75 to 1.5 by 1.5 to 3.15 microns. Motile with 1 or 2 polar flagella. Gram-negative.

Green fluorescent pigment produced in culture.

Gelatin: Liquefaction.

Beef-extract agar colonies: Grayish-white, margins corrugated, edges irregular.

Broth: Turbid in 36 hours.

Milk: Becomes alkaline and clears.

Nitrites not produced from nitrates.

Indole not formed.

No H_2S produced.

Not lipolytic (Starr and Burkholder, Phytopath., *32*, 1942, 601).

Acid but not gas from glucose, fructose, mannose, arabinose, xylose, mannitol and glycerol. Alkaline reaction from salts of acetic, citric, malic, lactic and succinic acids. Sucrose, lactose, maltose, raffinose, salicin, and salts of formic and tartaric acids not fermented.

Starch: No hydrolysis.

Growth in broth plus 5 per cent NaCl.

Facultative anaerobe.

Source: Two cultures isolated from spotted beans, one from England and one from Switzerland.

Habitat: Pathogenic on bean, *Phaseolus vulgaris*.

99a. *Pseudomonas viridiflava* var. *concentrica* (Petersen) *comb. nov.* (*Phytomonas viridiflava* var. *concentrica* Petersen, Tridsskr. f. Planteavl., *38*, 1932, 851; *Bacterium viridiflavum* var. *concentricum* Burgwitz, Phytopathogenic Bacteria, Leningrad, 1935, 127.) From M. L. *concentricus*, concentric, referring to the rings on the colonies.

Distinctive characters: Differs from *Pseudomonas viridiflava* in that it does not grow in Uschinsky's solution, and also in the shape of the colonies.

Source: Isolated from the stems and leaves of blighted beans in Denmark.

Habitat: Pathogenic on the bean, *Phaseolus vulgaris*.

100. **Pseudomonas ananas** Serrano. (Serrano, Philipp. Jour. Sci., *55*, 1934, 355; *Phytomonas ananas* and *Bacterium ananas* Serrano, *ibid.* (not to be confused with *Erwinia ananas* Serrano, *ibid.*, *36*, 1928, 271); *Bacterium serranoi* Burgwitz, Bact. Dis. of Plants, Leningrad, 1936.) From Brazilian Indian, *ananas*, pineapple; M.L. *Ananas*, generic name.

Rods: 0.6 by 1.8 microns. Motile with 1 to 4 polar flagella. Gram-negative.

Green fluorescent pigment produced in certain media.

Gelatin: Liquefied.

Beef-extract glucose agar colonies: White, with undulating edges, smooth to rugose, glistening to dull.

Beef-extract agar: Growth scant.

Broth: Feeble growth.

Milk: Becomes alkaline with curd.

Nitrites not produced from nitrates.

Indole not formed.

No H_2S formed.

Acid but not gas from glucose, xylose and mannitol. Feeble with lactose. No acid with sucrose.

Starch not hydrolyzed.

Optimum temperature 30° to 31°C. Maximum 45°C. Minimum 7° to 10°C.

Aerobic.

Habitat: Causes a rot of pineapples, *Ananas comosus*.

101. **Pseudomonas ligustri** (d'Oliveira) *comb. nov.* (*Bacterium ligustri* d'Oliveira, Revista Agron., *24*, 1936, 434.) From L. *ligustrum*, privet; M. L. *Ligustrum*, a generic name.

Rods: 0.5 to 0.7 by 1.3 to 3 microns. No chains. No capsules. Motile with 2 to 5 polar flagella. Gram-negative.

Green pigment produced on Dox agar, and in broth.

Gelatin: Liquefied.

Beef-extract agar colonies: Growth moderate. Milky white, circular, convex.

Broth: Turbid in 24 hours. No pellicle.

Milk: Coagulated in 6 days, and later digested. Litmus slightly acid.

Nitrites not produced from nitrates.

Indole not produced.

Ammonia not produced.

No gas from carbohydrates. Acid from glucose, galactose, arabinose and mannose. No acid from sucrose, maltose, lactose, raffinose, mannitol and salicin.

Source: From diseased Japanese privet in Lisbon, Portugal.

Habitat: Pathogenic on privet, *Ligustrum japonicum*.

102. **Pseudomonas sesami** Malkoff. (Malkoff, Cent. f. Bakt., II Abt., *16*, 1906, 665; *Bacterium sesami* Nakata, Ann. Phyt. Soc. Japan, *2*, 1930, 242; *Phytomonas sesami* Kovachersky, Ann. Univ. de Sofia, Fac. Agron., *8*, 1930, 464.) From Gr. *sesamum*, sesame; M. L. *Sesamum*, a generic name.

Synonym: Nakata (*loc. cit.*) lists *Bacterium sesamicola* Takimoto, Jour. Plant Protect. Tokyo, *8*, 1927, 433 (*Phytomonas sesamicola* Magrou, in Hauduroy et al., Dict. d. Bact. Path., 1937, 412).

Description from Nakata (*loc. cit.*).

Rods: 0.6 to 0.8 by 1.2 to 3.8 microns. Motile with 2 to 5 polar flagella. Gram-negative.

Green fluorescent pigment produced in culture.

Gelatin: Liquefaction rapid.

Beef-agar colonies: Circular, flat, striate, smooth, entire margins, white.

Broth: Growth rapid. No pellicle.

Milk: Alkaline. No coagulation.

Nitrites not produced from nitrates.

Indole not produced.

No H_2S produced.

Acid but not gas from glucose. No acid from lactose, sucrose or glycerol.

Starch not hydrolyzed.

Optimum temperature 30°C. Maximum 35°C. Minimum 0°C.

Facultative anaerobe.

Source: Isolated from brown spots on leaves and stems of sesame.

Habitat: Pathogenic on sesame.

103. **Pseudomonas tolaasii** Paine. (Paine, Ann. Appl. Biol., *5*, 1919, 210; *Phytomonas tolaasi* Bergey et al., Manual, 3rd ed., 1930, 259; *Bacterium tolaasi* Elliott, Bacterial Plant Pathogens, 1930, 226.) Named for A. G. Tolaas who first reported the species.

Rods: 0.4 to 0.5 by 0.9 to 1.7 microns. Motile with 1 to 5 polar flagella. Gram-negative.

Green fluorescent pigment produced in culture.

Gelatin: Liquefaction.

Bouillon agar: Streak develops in 24 hours, dirty bluish-white, wet-shining and slightly raised.

Broth: Turbid in 24 hours. Pellicle.

Milk: Becomes alkaline and clears.

Nitrites not produced from nitrates.

Indole production slight.

Acid but not gas from glucose. No acid from lactose or sucrose.

Starch hydrolysis feeble.

Optimum temperature 25°C.

Source: Isolated in England from brown-spot of cultivated mushrooms.

Habitat: Pathogenic on cultivated mushrooms.

104. **Pseudomonas xanthochlora** (Schuster) Stapp. (*Bacterium xanthochlorum* Schuster, Arbeit. a. d. Kaiserl. Biolog. Anstalt. f. Land. u. Forstw., *8*, 1912, 452; *Phytomonas xanthochlora* Bergey et al., Manual, 1st ed., 1923, 180; Stapp, in Sorauer, Handbuch der Pflanzenkrankheiten, *2*, 5 Auf., 1928, 213.) From Gr. *xanthus*, yellow; *chlorus*, green.

Description from Erw. Smith, Bacteria in Rel. to Plant Dis., *3*, 1914, 272.

Rods: 0.75 to 1.5 by 3.0 microns. Motile with 1 to 3 flagella. Gram-negative.

Green fluorescent pigment produced in culture.

Gelatin: Slow liquefaction.

Agar colonies: Circular, slightly raised, yellow-white.

Broth: Strong clouding in 24 hours. A white pellicle.

Milk: Slow coagulation and clearing.

Nitrites are produced from nitrates.

Indole is produced after 10 days.

Hydrogen sulfide produced slowly.

Acid but not gas from glucose and galactose.

Optimum temperature 27°C. Maximum 44°C. Minimum 2°C.

Source: Isolated from rotting potato tubers in Germany.

Habitat: Pathogenic on potato tubers and a number of unrelated plants.

105. **Pseudomonas rhizoctonia** (Thomas) *comb. nov.* (*Aplanobacter rhizoctonia* Thomas, Ohio Agr. Exp. Sta. Bull. 359, 1922, 211; *Bacterium rhizoctonia* Stapp, in Sorauer, Handbuch der Pflanzenkrankheiten, *2*, 5 Auf., 1928, 290; *Phytomonas rhizoctonia* Burkholder, Phytopath., *20*, 1930, 7.) From Gr. *rhizo*, root; *ctonus*, murder.

Rods: 0.5 to 0.85 by 1.4 to 1.9 microns. Non-motile. Gram-negative.

Green fluorescent pigment produced in culture.

Gelatin: Liquefaction.

Nutrient agar colonies: Greenish-yellow, later olive-buff, circular, raised, slightly viscid.

Broth: Turbid, pyrite yellow.

Milk: Alkaline; clears.

Nitrites are produced from nitrates.

Indole reaction very slight.

No H_2S formed.

Starch: Potato starch slightly hydrolyzed.

Growth in 8 per cent salt.

Optimum temperature 25° to 27°C. Maximum 38°C. Minimum 0°C.

Source: Isolated from roots of lettuce showing the rosette disease.

Habitat: Pathogenic on roots of lettuce.

106. **Pseudomonas barkeri** (Berridge) Clara. (Bacillus of pear blossom disease, Barker and Grove, Ann. Appl. Biol., *1*, 1914, 94; Barker and Grove's organism, Doidge, Ann. Appl. Biol., *4*, 1917, 50; *B. barkeri* Berridge, Ann. Appl. Biol., *11*, 1924, 73; *Phytomonas barkeri* Bergey et al., Manual, 3rd ed., 1930, 265; *Bacterium barkeri* Elliott, Bacterial Plant Pathogens, 1930, 95; Clara, Science, *75*, 1934, 11.) Named for B. T. P. Barker who first reported the species.

Description from Doidge (*loc. cit.*).

Rods: 0.5 to 0.8 by 2 to 4 microns. Motile with 1 to 4 polar flagella. Gram-negative (Burkholder), not Gram-positive as stated.

Green fluorescent pigment produced in culture.

Gelatin: Liquefaction.

Agar: Growth is white, feeble, flat, glistening, smooth edged.

Broth: Slightly turbid in 24 hours.

Milk: Slowly cleared.

Nitrites not produced from nitrates.

Indole not formed unless culture warmed.

Starch slowly digested.

Source: Barker made many cultures

from blighted pear blossoms. Doidge received a culture from Barker.

Habitat: Causes a blossom blight of pear.

107. **Pseudomonas gladioli** Severini. (Severini, Annali d. Bot., Rome, *11*, 1913, 420; *Bacterium gladioli* Elliott, Bact. Plant Pathogens, 1930, 132; *Phytomonas gladioli* Magrou, in Hauduroy et al., Dict. d. Bact. Path., Paris, 1937, 356.) From L. *gladiolus*, a little sword; M. L. *Gladiolus*, a generic name.

Rods: 0.6 by 2.3 to 2.8 microns. Motile with one or more polar flagella. Gram-negative.

A pale yellow water-soluble pigment found, later orange.

Gelatin colonies: Cream-colored, wart-like. Rapid liquefaction.

Milk: Coagulated and slowly peptonized.

Nitrites not produced from nitrates.

Indole not formed.

No gas.

Aerobic.

Optimum temperature 28° to 30°C.

Habitat: Causes a corm rot of gladiolus and other tubers.

108. **Pseudomonas mellea** Johnson. (*Bacterium melleum* Johnson, Jour. Agr. Res., *23*, 1923, 489; Johnson, *loc. cit.*, 489; *Phytomonas mellea* Bergey et al., Manual, 3rd ed., 1930, 254.) From L. *melleus*, of or belonging to honey, the color of the colonies.

Rods: 0.6 by 1.8 microns. Capsules. Motile with 1 to 7 polar flagella. Gram-negative.

Green fluorescent pigment produced in culture.

Gelatin: Liquefied.

Potato - glucose agar: Abundant growth, smooth, glistening, viscid, honey-colored.

Broth: Turbid in 24 hours. Pellicle.

Milk: Alkaline; clears.

Nitrites not produced from nitrates.

Indole not formed.

No H_2S formed.

Starch hydrolysis feeble.

Growth inhibited by 4 per cent salt.

Optimum temperature, 26° to 28°C. Maximum 36°C.

Facultative anaerobe.

Distinctive character: Differs from *Pseudomonas pseudozoogloeae* in that it produces on tobacco a brown instead of a black spot with a halo, is orange-yellow in culture, and turns milk alkaline.

Source: Isolated from brown rusty spots on tobacco in Wisconsin.

Habitat: Pathogenic on leaves of tobacco, *Nicotiana tabacum*.

109. **Pseudomonas betlis** (Ragunathan) *comb. nov.* (*Bacterium betle* Ragunathan, Ann. Roy. Card., Peradeniya, Ceylon, *11*, 1928, 51; *Aplanobacter betle* Elliott, Bact. Plant Pathogens, 1930, 4; *Phytomonas betlis* Magrou, in Hauduroy et al., Dict. d. Bact. Path., Paris, 1937, 337.) From Malayan, *betle*, *betel*, a kind of pepper, *Piper betle*.

Rods: 0.5 by 1.5 to 2.5 microns, occurring singly or in short chains. Non-motile. Gram-negative.

Green pigment formed in nutrient gelatin and in broth.

Gelatin: Liquefaction.

Bovril agar colonies: Honey-yellow, circular at first, later echinulate. Raised, smooth and shiny.

Broth: Surface becomes cloudy in 2 days. Pellicle.

No gas from lactose, maltose or sucrose.

Starch is reduced.

Aerobic.

Source: Five cultures isolated from leaf spots on the betel vine.

Habitat: Pathogenic on the betel vine, *Piper betle*.

110. **Pseudomonas panacis** (Takimoto) Dowson. (*Bacterium panaxi* Nakata and Takimoto, Bul. Agr. Sta. Chosen, *5*, 1922, 1; *Phytomonas panaxi* Magrou, in Hauduroy et al., Dict. d. Bact. Path., Paris, 1937, 389; Dowson, Trans. Brit.

Mycol. Soc., *26*, 1943, 10.) From Gr. *panax* (*panicis*), a plant heal-all; M. L. *Panax*, a generic name.

Description from Elliott, Bact. Plant Pathogens, 1930, 173.

Rods: 0.5 by 1.3 to 1.5 microns. Chains. Motile with 4 to 6 polar flagella. Gram-negative.

Green fluorescent pigment produced in culture.

Gelatin: Slight liquefaction.

Agar colonies: White.

Milk: Coagulated.

No gas from sugars.

Habitat: Causes a root rot of ginseng, *Panax quinquefolium*.

111. **Pseudomonas aleuritidis** (McCulloch and Demaree) Stapp. (*Bacterium aleuritidis* McCulloch and Demaree, Jour. Agr. Res., *45*, 1932, 339; Stapp, Bot. Rev., *1*, 1935, 408; *Phytomonas aleuritidis* Magrou, in Hauduroy et al., Dict. d. Bact. Path., Paris, 1937, 328.) From Gr. *aleurites*, of wheaten flour; M. L. *Aleurites*, generic name.

Rods: 0.6 to 0.7 by 1.1 to 3 microns. Motile with 1 to 5 polar, rarely bipolar, flagella. Capsules present. Gram-negative.

Green fluorescent pigment produced in certain media.

Gelatin: Not liquefied.

Beef agar slants: Growth is thin, white and viscid.

Broth: A heavy white surface growth in 24 hours. Sediment.

Milk: Becomes alkaline, but no separation.

Nitrites are produced from nitrates.

Indole test feebly positive.

Hydrogen sulfide test feebly positive.

Acid but no gas from glucose, galactose and glycerol. Slow acid production from sucrose, maltose and lactose.

Starch hydrolysis feeble.

Optimum temperature 27° to 28°C. Maximum temperature 37°C.

Optimum pH 6.2 to 6.8. pH range 5.4 to 8.9.

Source: Isolations from naturally infected tung oil trees in Georgia.

Habitat: Pathogenic on the tung oil tree (*Aleurites fordi*), on the bean (*Phaseolus vulgaris*) and the castor bean (*Ricinus communis*).

112. **Pseudomonas glycinea** Coerper. (*Bacterium glycineum* Coerper, Jour. Agric. Research, *18*, 1919, 188; Coerper, *loc. cit.*, 188; *Phytomonas glycinea* Burkholder, Phytopath., *16*, 1926, 922.) From *glycys*, sweet; *ine*, like; M.L. *Glycine*, generic name.

Synonym: *Bacterium sojae* Wolf, Phytopath., *10*, 1920, 132 (*Phytomonas sojae* Burkholder, Phytopath., *16*, 1926, 922; *Pseudomonas sojae* Stapp, in Sorauer, Handb. d. Pflanzenkrankheiten, *2*, 5 Aufl., 1928, 174). See Elliott, Bact. Plant Pathogens, 1930, 134; and Shunk and Wolf, Phytopath., *11*, 1921, 18.

Rods: 1.2 to 1.5 by 2.3 to 3 microns. Motile with polar flagella. Gram-negative.

Green fluorescent pigment produced in culture.

Gelatin: Not liquefied.

Beef-peptone agar colonies: Appear in 24 hours. Circular, creamy white, smooth, shining and convex. Margins entire. Butyrous in consistency.

Milk: Litmus turns blue and later a separation of the milk occurs. Casein not digested.

Nitrites not produced from nitrates.

Indole test feebly positive.

Not lipolytic (Starr and Burkholder, Phytopath., *32*, 1942, 601).

Starch not hydrolyzed.

Acid from glucose and sucrose.

Optimum temperature 24° to 26°C. Maximum 35°C. Minimum 2°C.

Facultative anaerobe.

Source: A number of cultures isolated from soy beans in Wisconsin.

Habitat: Pathogenic on soybean, *Glycine max* (*Soja max*).

112a. *Pseudomonas glycinea* var. *japonica* (Takimoto) *comb. nov.* (*Bac-*

terium soyae var. *japonicum* Takimoto, Jour. Plant Protect. Tokyo, *14*, 1927, 556; *Bacterium glycineum* var. *japonicum* Elliott, Bact. Plant Pathogens, 1930, 136; *Phytomonas glycinea* var. *japonica* Magrou, in Hauduroy et al., Dict. d. Bact. Path., Paris, 1937, 358.) From M. L. *Japonicus*, japanese.

Distinctive characters: Differs slightly from *Pseudomonas glycinea* in size of cell, length of chains, action in milk, and color in media. Okabe (Jour. Soc. Trop. Agr., Formosa, *5*, 1933, 162) gives a description of the organism which leads one to believe the differences are not great enough to be varietal.

Source: Isolated from leaf spots on soy bean in Formosa.

Habitat: Pathogenic on soy bean, *Glycine max*.

113. **Pseudomonas savastanoi** (Erw. Smith) Stevens. (*Bacterium savastanoi* Erw. Smith, U. S. Dept. Agr. Plant Ind. Bull. 131, 1908, 31; Stevens, The Fungi which Cause Plant Diseases, 1913, 33; *Phytomonas savastanoi* Bergey et al., Manual, 1st ed., 1923, 190.) Named for F. Savastano, the Italian plant pathologist.

NOTE: Smith (*loc. cit.*) lists and discards the following species since they were either mixed cultures or names with no descriptions: *Bacterium oleae* Arcangeli, Istit. Bot. delle R. Univ. di Pisa, Ricerche e Lavori, fasc. *1*, 1886, 109; *Bacillus oleae tuberculosis* Savastano, Atti. R. Accad. Naz. Lincei Rend. Cl. Sci. Fis., Mat. e Nat., *5*, 1889, 92; *Bacillus prillieuxianus* Trevisan, I generi e le specie delle Batteriacee, Milano, 1889, 19; *Bacillus oleae* De Toni and Trevisan, in Saccardo, Sylloge Fungorum, *8*, 1889, 982.

Description from Brown, Jour. Agr. Res., *44*, 1932, 711.

Rods: 0.4 to 0.8 by 1.2 to 3.3 microns. Motile with 1 to 4 polar flagella. Gram-negative.

Green fluorescent pigment found in culture.

Gelatin: No liquefaction.

Beef agar colonies: White, smooth, flat, glistening, margins erose or entire.

Broth: Turbid on the second day. No pellicle or ring.

Milk: Becomes alkaline.

Nitrites not produced from nitrates.

No H_2S produced.

Acid but not gas from glucose, galactose and sucrose.

Starch is hydrolyzed.

Optimum temperature 23° to 24°C. Maximum 32°C. Minimum 1°C.

Optimum pH 6.8 to 7.0. Maximum 8.5. Minimum 5.6.

Aerobic.

Source: Smith isolated his cultures from olive galls collected in California.

Habitat: Pathogenic on olive.

113a. *Pseudomonas savastanoi* var. *fraxini* (Brown) Dowson. (*Bacterium savastanoi* var. *fraxini* Brown, Jour. Agr. Res., *44*, 1932, 721; *Phytomonas savastanoi* var. *fraxini* Magrou, in Hauduroy et al., Dict. d. Bact. Path., Paris, 1937, 410; *Pseudomonas fraxini* Skoric, Ann. Exp. For. Zagreb, *6*, 1938, 66; Dowson, Trans. Brit. Mycol. Soc., *26*, 1943, 11.) From M. L. *Fraxinus*, a generic name.

Distinctive characters: Differs but slightly from *Pseudomonas savastanoi*, but is pathogenic on ash and not on olive.

Source: Three cultures isolated from cankers on ash.

Habitat: Pathogenic on ash, *Fraxinus excelsior* and *F. americana*.

114. **Pseudomonas tonelliana** (Ferraris) *comb. nov.* (*Bacterium tonellianum* Ferraris, Trattato di Patologia e Terapia Vegetale, 3rd ed., *1*, 1926, 104; *Phytomonas tonelliana* Adams and Pugsley, Jour. Dept. Agr. Victoria, *32*, 1934, 304.) Named for Tonelli, the Italian botanist.

Synonym: *Pseudomonas savastanoi* var. *nerii* C. O. Smith, Phytopath., *18*, 1928, 503.

Description from Smith (*loc. cit.*) unless otherwise noted.

Rods: 0.5 to 0.6 by 1.5 to 2.5 microns. Motile with 1 to 3 polar flagella. Gram-negative (Adams and Pugsley, *loc. cit.*).

Gelatin: No liquefaction.

Potato glucose agar colonies: Flat, circular, shining, margins somewhat undulated.

Broth: Dense clouding with partial pellicle.

Milk: Alkaline. No separation.

Nitrites not produced from nitrates (Adams and Pugsley).

Indole produced. Not produced (Adams and Pugsley).

Acid but not gas from glucose and sucrose. No acid from lactose (Adams and Pugsley).

Starch not hydrolyzed (Adams and Pugsley).

Distinctive character: *Pseudomonas savastanoi* is similar in culture but is not pathogenic on oleanders.

Source: Both Ferraris and C. O. Smith isolated the pathogen from galls on oleander.

Habitat: Pathogenic on oleander, *Nerium oleander*.

115. **Pseudomonas calendulae** (Takimoto) Dowson. (*Bacterium calendulae* Takimoto, Ann. Phytopath. Soc. Japan, *5*, 1936, 341; *Phytomonas calendulae* Burkholder, in Manual, 5th ed., 1939, 201; Dowson, Trans. Brit. Mycol. Soc., *26*, 1943, 9.) From Latin, *calendae*, throughout the month; M.L. *Calendula*, a generic name.

Rods: 0.5 by 1 to 2 microns. Motile with 1 to 3 polar flagella. Gram-negative.

Green fluorescent pigment produced in Uschinsky's and in Cohn's solutions.

Gelatin: Not liquefied.

Agar colonies: Circular, smooth, flat, dirty white.

Broth: Turbid.

Milk: No coagulation.

Nitrites not produced from nitrates.

Indole formed in small amount.

No H_2S produced.

Acid but not gas from glucose and glycerol. No acid from lactose or sucrose.

Starch not hydrolyzed.

Optimum temperature 27° to 30°C. Maximum 37°C. Minimum 0° to 7°C.

Habitat: Pathogenic on marigolds, *Calendula officinalis*.

116. **Pseudomonas cichorii** (Swingle) Stapp. (*Phytomonas cichorii* Swingle, Phytopath., 15, 1925, 730; Stapp, in Sorauer, Handbuch der Pflanzenkrankheiten, *2*, 5 Auf., 1928, 291; *Bacterium cichorii* Elliott, Bact. Plant Pathogens, 1930, 112.) From Gr. *cichoria*, chicory; M. L. *Cichorium*, generic name.

Probable synonyms: *Pseudomonas endiviae* Kotte, Phyt. Ztschr., *1*, 1930, 609; *Phytomonas endiviae* (Kotte) Clara, Cornell Agr. Exp. Sta. Mem. 159, 1934, 26; and *Bacterium formosanum* Okabe, Jour. Soc. Trop. Agr., Formosa, *7*, 1935, 65.

Description from Clara (*loc. cit.*) which is a description of a culture of *Pseudomonas endiviae* from Kotte. Swingle's description is very meager.

Rods: 0.75 to 1.5 by 1.5 to 3.75 microns. Motile with 1 or 2 polar flagella. Gram-negative.

Green fluorescent pigment produced in culture.

Gelatin: No liquefaction.

Beef-extract agar colonies: Circular, grayish-white with bluish tinge, raised with slightly irregular edges.

Broth: Turbid in 36 hours with a smooth viscous pellicle.

Milk: Alkaline.

Nitrites not produced from nitrates.

Indole not formed.

No H_2S formed.

Not lipolytic (Starr and Burkholder, Phytopath., *32*, 1942, 601).

Acid but not gas from glucose, galactose, fructose, mannose, arabinose, xylose, mannitol and glycerol. Alkaline production from salts of acetic, citric, lactic, malic, succinic and tartaric acids.

Rhamnose, maltose, sucrose, lactose, raffinose and salicin not utilized.

Starch not hydrolyzed.

Slight growth in broth plus 6 per cent NaCl.

Optimum pH 6.8 to 7.1. Maximum 9.2 to 9.4. Minimum 5.0 to 5.3 (Kotte, Phyt. Ztsch., *2*, 1930, 453).

Facultative anaerobe.

Distinctive characters: Differs from *Pseudomonas intybi* in that it does not liquefy gelatin or reduce nitrates to nitrites.

Source: Isolated from rot of French endive, *Cichorium intybus* by Swingle and by Okabe, and from *C. endivia* by Kotte.

Habitat: Pathogenic on endive, lettuce and larkspur.

117. **Pseudomonas cissicola** (Takimoto) *comb. nov.* (*Aplanobacter cissicola* Takimoto, Ann. Phytopath. Soc. Japan., *9*, 1939, 43.) From Greek, *cissus*, ivy; M. L. *Cissus* a generic name.

Rods: 0.5 to 0.9 by 1.0 to 2.0 microns. Non-motile. Capsules. Gram-negative.

Green fluorescent pigment formed in Uschinsky's solution.

Gelatin: No liquefaction.

Potato-extract agar colonies: Circular, convex, smooth, and dirty white.

Broth: Feeble clouding followed by precipitation of pellicle and rim.

Nitrites not produced from nitrates.

Indole not formed.

Hydrogen sulfide not produced.

No acid nor gas from sucrose, glucose, lactose and glycerol.

Starch is not digested.

Salt toleration is 3 per cent.

Optimum temperature 30°C. Maximum 35°C. Minimum 10°C. Thermal death point 49° to 50°C.

Source: Isolated from black spots on leaves of Japanese ivy, *Cissus japonica* in Japan.

Habitat: Pathogenic only on *Cissus japonica*.

118. **Pseudomonas nectarophila** (Doidge) Rosen and Bleeker. (*Bacterium nectarophila* Doidge, Ann. Appl. Biol., 4, 1917, 73; *Phytomonas nectarophila* Bergey et al., Manual, 3rd ed., 1930, 262; Rosen and Bleeker, Jour. Agr. Res., *46*, 1933, 98.) From Gr. *nectar*, nectar; *philus*, loving.

Rods: 0.5 to 0.7 by 0.6 to 1.5 microns. Motile with 1 to 5 polar flagella. Capsules. Gram-negative.

Green fluorescent pigment produced in culture.

Gelatin: No liquefaction.

Nutrient agar colonies: Yellowish-white, wet-shining, smooth, margins irregular.

Broth: Heavy turbidity in 24 hours. Sediment.

Milk: Cleared.

Nitrites not produced from nitrates.

Indole not formed.

Acid from glucose and galactose. No acid from sucrose.

Starch hydrolysis feeble.

Optimum temperature 25 to 30°C.

Facultative anaerobe.

Distinctive character: Differs from *Pseudomonas barkeri* in that it does not liquefy gelatin, nor produce indole. Produces capsules.

Source: Isolated from blighted pear blossoms in South Africa.

Habitat: Pathogenic on pear blossoms.

119. **Pseudomonas viburni** (Thornberry and Anderson) Stapp. (*Phytomonas viburni* Thornberry and Anderson, Phytopath., *21*, 1931, 912; Stapp, Bot. Rev., *1*, 1935, 407; *Bacterium viburni* Burgwitz, Phytopathogenic Bacteria, Leningrad, 1935, 160.) From L. *viburnum*, the wayfaring tree; M. L. *Viburnum*, a generic name.

Rods: 0.5 to 1.0 by 1 to 2.0 microns. Capsules present. Motile with 2 to 4 polar flagella. Gram-negative (Burkholder); not Gram-positive as stated.

Green fluorescent pigment produced in culture (Burkholder).

Gelatin: No liquefaction.

Glucose beef-extract colonies: Dull gray, circular, edges entire.

Broth: Turbid with pellicle.

Milk: Alkaline.

Nitrites not produced from nitrates.

Indole not formed.

No H_2S formed.

Not lipolytic (Starr and Burkholder, Phytopath., *32*, 1942, 601).

Acid from glucose and galactose, but not sucrose (Burkholder).

Starch: No hydrolysis.

Slight growth in 3.5 per cent salt (Burkholder).

Optimum temperature 25°C. Minimum 12°C. Maximum 35°C.

Aerobic.

Source: Isolated from angular leaf spots and stem lesions on arrow-wood, *Viburnum opulus*, etc.

Habitat: Pathogenic on *Viburnum spp.*

120. **Pseudomonas mori** (Boyer and Lambert) Stevens. (*Bacterium mori* Boyer and Lambert, Compt. rend. Acad. Sci. Paris, *117*, 1893, 342; *Bacterium mori* Boyer and Lambert *emend.* Erw. Smith, Science, *31*, 1910, 792; Stevens, The Fungi which Cause Plant Diseases, 1913, 30; *Bacillus mori* Holland, Jour. Bact., *5*, 1920, 222; *Phytomonas mori* Bergey et al., Manual, 1st ed., 1923, 191.) From Gr. *morum*, mulberry; M. L. *Morus*, a generic name.

Synonyms: Elliott (Bact. Plant Pathogens, 1930, 166) lists *Bacillus cubonianus* Macchiati, Staz. Sperim. Agr. Ital., *23*, 1892, 228 (Macchiati described the disease due to *Pseudomonas mori*, but gave an incorrect description of the pathogen); also *Bacterium cubonianum* Ferraris, Curiano le Plante, *6*, 1928, 180 (Ferraris uses Macchiati's name but the description of *Pseudomonas mori*).

Description from Smith (*loc. cit.*).

Rods: 0.9 to 1.3 by 1.8 to 4.5 microns. Motile with a polar flagellum. Gram-negative.

Green fluorescent pigment produced in culture.

Gelatin: Not liquefied.

Agar colonies: White, slow-growing, smooth, flat, edges entire becoming undulate.

Milk: Becomes alkaline and clears.

Nitrites not produced from nitrates.

Indole none or feeble production.

Hydrogen sulfide not produced (Okabe, Jour. Soc. Trop. Agr., *5*, 1933, 166).

No growth in broth plus 4 per cent salt (Okabe, *loc. cit.*).

No gas from carbohydrates.

Temperature range 1°C to 35°C.

Source: Smith isolated the pathogen from blighted shoots of mulberry from Georgia. Also received cultures from Arkansas and the Pacific Coast.

Habitat: Pathogenic on mulberry, *Morus*.

121. **Pseudomonas stizolobii** (Wolf) *comb. nov.* (*Aplanobacter stizolobii* Wolf, Phytopath., *10*, 1920, 79; *Bacterium stizolobii* McCulloch, Phytopath., *18*, 1928, 460; *Phytomonas stizolobii* Bergey et al., Manual, 3rd ed., 1930, 280.) From Gr. *stizo*, to prick; *lobium*, a little lobe; *Stizolobium*, a generic name.

Rods: 0.6 to 0.7 by 1.0 to 1.6 microns. Non-motile (Wolf). Motile with a short polar flagellum (McCulloch). Capsules. Gram-negative.

Gelatin: No liquefaction.

Agar colonies: Circular, smooth, white, raised and opaque. Margins entire to slightly undulate.

Broth: Slightly turbid throughout. No pellicle or ring.

Milk: Alkaline.

Nitrites not produced from nitrates.

Indole not formed.

No acid or gas in peptone broth plus sugars.

Starch not hydrolyzed.

Optimum temperature 25° to 28°C.

Distinctive characters: Differs from *Pseudomonas sojae* (*Pseudomonas glycinea*) in the smaller size of cell, and absence of pellicle and dense clouding of broth. The pathogen does not infect soy bean.

Source: Isolated from the leaf spot of velvet bean.

Habitat: Pathogenic on velvet bean, ***Stizolobium deeringianium.***

122. **Pseudomonas viciae** Uyeda. (Uyeda in Takimoto, Jour. Plant Protect., Japan, *2*, 1915, 845; *Bacterium viciae* Nakata, see Elliott, Bact. Plant Pathogens, 1930, 259; *Phytomonas viciae* Magrou, in Hauduroy et al., Dict. d. Bact. Path., Paris, 1937, 430.) From L. *vicia*, vetch; M. L. *Vicia*, a generic name.

Rods: 0.5 to 0.8 by 1.2 to 2.0 microns. Motile with 2 to 4 polar flagella. Gram-positive.

Green fluorescent pigment produced in culture.

Gelatin colonies: Pale white, glistening, finally turning brown. No liquefaction.

Milk: Coagulates and clears.

Nitrites not produced from nitrates.

No H_2S produced.

Facultative anaerobe.

Habitat: Pathogenic on the broad bean (*Vicia faba*), the turnip (*Brassica rapa*), the carrot (*Daucus carota*) and the sweet potato (*Ipomoea batatas*).

123. **Pseudomonas alliicola** Burkholder. (Burkholder, Phytopath., *32*, 1942, 146; *Phytomonas alliicola* Burkholder, *ibid.*) From L. *allium*, onion; *-cola*, dweller.

Rods: 0.7 to 1.4 by 1.05 to 2.8 microns. Motile with 1 to several polar flagella, at times bi-polar. Gram-negative.

Gelatin: Liquefaction.

Beef-extract peptone agar streaks: Moderate in growth, white at first, later dirty in appearance, edges wavy, consistency viscid. Medium deep brown.

Potato-glucose agar frequently becomes greenish.

Broth: Turbid with light pellicle. Brown.

Milk: Cleared and litmus reduced. Neutral.

Nitrites produced from nitrates.

Indole not produced.

Hydrogen sulfide not produced.

Lipolytic action very strong.

Acid but no gas from l-arabinose, d-xylose, rhamnose, glucose, d-galactose, fructose, d-lactose, maltose, sucrose, glycerol, mannitol and salicin. Alkali from salts of acetic, citric, formic, hippuric, lactic, malic, succinic, tartaric acids.

Starch not hydrolysed.

Slight growth in broth plus 4 per cent salt.

Aerobic.

Optimum temperature 30°C. Maximum 41°C. Minimum 5°C.

Source: Seven isolates from storage rot of onion bulbs.

Habitat: Pathogenic on onion bulbs, *Allium cepa*.

124. **Pseudomonas gardeniae** Burkholder and Pirone. (Burkholder and Pirone, Phytopath., *31*, 1941, 194; *Phytomonas gardeniae* Burkholder and Pirone, *ibid.*) From M. L. *Gardenia*, a generic name.

Rods: 0.75 by 2.4 microns. Motile with 1 to 2 polar flagella. Gram-negative.

Gelatin: Liquefaction.

Beef-extract peptone agar colonies: Growth fair, white to dirty gray and viscid. Medium becoming dark brown.

Potato-glucose agar: No brown color.

Broth: Turbid with pellicle. Dark brown.

Milk: Soft curd with pellicle. Clears in zones. Litmus reduced.

Nitrites produced from nitrates.

Hydrogen sulfide not produced.

Indole not formed.

Acid from glucose, galactose, xylose, rhamnose, sucrose, maltose, mannitol, glycerol, and salicin. Alkali produced from the salts of citric, malic, malonic, succinic, tartaric and hyppuric acids. Good growth in tyrosine and in asparagine broth.

Starch is not hydrolyzed.

Aerobic.

Source: Eight isolates from leaf spots of gardenias in New Jersey.

Habitat: Pathogenic on leaves of *Gardenia jasminoides*.

125 **Pseudomonas caryophylli** Burkholder. (Burkholder, Phytopath., *31*,

1941, 143; *Phytomonas caryophylli*, Burkholder, *ibid.*) From M. L. *Caryophyllus*, an old generic name.

Rods: 0.35 to 0.95 by 1.05 to 3.18 microns. At times slightly curved. Motile with 1 to several polar flagella. Frequently bipolar. Gram-negative.

Gelatin: Liquefaction after 3 to 4 weeks.

Potato glucose agar colonies: 3 to 4 mm in diameter, circular, smooth, glistening, edges entire. Color is tan to gray mauve. Old culture dark brown. Consistency butyrous.

Broth: Turbid with a white sediment.

Milk: Litmus slowly becomes blue. Slight reduction at bottom of tube. No clearing.

Nitrites produced from nitrates. Also ammonia and gas are produced in a synthetic nitrate medium. Asparagine, KNO_3 and $NH_4H_2PO_4$ can be utilized.

Indole not formed.

Hydrogen sulfide not formed.

Lipolytic action slight to moderate.

Acid from l-arabinose, d-xylose, rhamnose, glucose, d-galactose, fructose, d-lactose, maltose, and sucrose, glycerol, mannitol, and salicin. Alkali with sodium salts of acetic, citric, formic, hippuric, lactic, malic, maleic, succinic and tartaric acid.

Starch not hydrolyzed.

Aerobic.

Optimum temperature 30° to 33°C. Maximum 46°C. Minimum 5°C. or less.

Slight growth in broth plus 3.5 per cent salt.

Source: Isolated first by L. K. Jones and later by W. H. Burkholder from dying carnation plants from Spokane, Washington. Twelve isolates used in description.

Habitat: Pathogenic on roots and stalks of the carnation, *Dianthus caryophyllus*.

126. **Pseudomonas solanacearum** Erw. Smith. (*Bacillus solanacearum* Erw. Smith, U. S. Dept. Agr., Div. Veg. Phys. and Path., Bul. 12, 1896, 10; *Bacterium solanacearum* Chester, Ann. Rept. Del. Col. Agr. Exp. Sta., *9*, 1897, 73; Erw. Smith, Bacteria in Relation to Plant Diseases, *3*, 1914, 178; *Phytomonas solanacearum* Bergey et al., Manual, 1st ed., 1923, 186.) From L. *solanum* nightshade; M. L. *Solanaceae*, a plant family.

Probable synonyms: Elliott (Bact. Plant Pathogens, 1930, 203) lists the following: *Bacillus nicotianae* Uyeda, Cent. f. Bakt., II Abt., *13*, 1904, 327; *Bacillus sesami* Malkoff and *Pseudomonas sesami* Malkoff, Cent. f. Bakt., II Abt., *16*, 1906, 664; *Bacillus musae* Rorer, Phytopath., *1*, 1911, 45; *Bacillus musarum* Zeman, Rev. Facul. Agr. Univ., La Plat, *14*, 1921, 17; *Erwinia nicotianae* Bergey et al., Manual, 1st ed., 1923, 172; *Phytomonas ricini* Archibald, Trop. Agr., Trinidad, *4*, 1927, 124.

Description taken from Elliott (*loc. cit.*).

Rods: 0.5 to 1.5 microns. Motile with a polar flagellum. Gram-negative.

Gelatin: Nakata (Jour. Sci. Agr. Soc. Tokyo, *294*, 1927, 216) states there are two forms, one of which shows slight liquefaction. The other shows no liquefaction.

Agar colonies: Small, irregular, roundish, smooth, wet-shining, opalescent, becoming brown.

Broth: Slight pellicle. Broth turns brown.

Milk: Cleared without precipitation of casein.

Nitrites produced from nitrates.

Indole not formed.

Hydrogen sulfide not produced (Burkholder).

Glucose, sucrose, glycerol, sodium citrate, peptone, tyrosine, asparagine and glutanic acid are utilized (Mushin, Austral. Jour. Expt. Biol. and Med., *16*, 1938, 325).

Nitrogen sources utilized are ammonia, nitrates (KNO_3) asparagine, tyrosine, peptone and glutamic acid, but not potassium nitrite (Mushin, *loc. cit.*).

Starch not hydrolyzed.

Optimum temperature 35° to 37°C. Maximum 41°C. Minimum 10°C.

Pathogenicity readily lost in culture.

Source: Isolated from brown-rot of solanaceous plants.

Habitat: Soil pathogen in warm moist climates attacking numerous species of plants, especially potato, tobacco, and tomato.

126a. *Pseudomonas solanacearum* var. *asiatica* (Erw. Smith) Stapp. (*Bacterium solanacearum* var. *asiaticum* Erw. Smith, Bact. in Relation to Plant Diseases, *3*, 1914, 282; Stapp, in Sorauer, Handbuch der Pflanzenkrankheiten, *2*, 5 Auf., 1928, 253; *Phytomonas solanacearum* var. *asiatica* Magrou, in Hauduroy et al., Dict. d. Bact. Path., Paris, 1937, 414.) From Gr. *asiaticus*, asiatic.

Distinctive characters: Differs from *Pseudomonas solanacearum* in that it turns litmus milk and cream red.

Source: Isolated by J. A. Honing from diseased tobacco plants in Medan, Sumatra.

127. **Pseudomonas castaneae** (Kawamura) *comb. nov.* (*Bacterium castaneae* Kawamura, Ann. Phytopath. Soc. Japan, *3*, 1934, 15; *Phytomonas castaneae* Magrou, in Hauduroy et al., Dict. d. Bact. Path., Paris, 1937, 343.) From M. L. *Castanea*, a generic name.

Rods: 0.8 to 1.2 by 1.0 to 1.8 microns. Motile with 1 to 5 polar flagella. Gram-negative.

Gelatin: Liquefied.

Beef agar colonies: White, circular, edges slightly undulate, viscid.

Milk: No coagulation. Peptonized.

Acid but not gas from glucose, sucrose and glycerol. No acid from lactose.

Optimum temperature 25° to 27°C. Maximum 35°C. Minimum 3°C.

Facultative anaerobe.

Habitat: Causes water-soaked spotting on leaves and shoots of chestnut, *Castanea*.

128. **Pseudomonas seminum** Cayley. (Cayley, Jour. Agr. Sci., *8*, 1917, 461; *Bacterium seminum* Stevenson, Foreign Plant Dis., U.S.D.A. Office of Sec'y., 1926, 141; *Phytomonas seminum* Bergey et al., Manual, 3rd ed., 1930, 272.) From L. *semen* (*seminus*) seed.

Rods: 1.0 by 4.0 to 5.0 microns. Spore-like bodies present. Capsules. Motile with a single flagellum. Gram-positive.

Gelatin: Rapid liquefaction.

Agar colonies: White, more or less circular, transparent, spreading.

Broth: Turbid. Pellicle.

Litmus milk: Milk becomes clear and apricot color.

Nitrites produced from nitrates.

Acid but not gas from glucose and sucrose. No acid from lactose.

Starch: No hydrolysis.

Optimum temperature 25°C.

Facultative anaerobe.

Source: Isolated from seeds, stems and pods of diseased peas in England.

Habitat: Pathogenic on peas.

129. **Pseudomonas passiflorae** (Reid) *comb. nov.* (*Phytomonas passiflorae* Reid, New Zealand Jour. Sci. and Tech., *22*, 1939, 264a.) From L. *passio*, passion; *flora*, flower; M. L. *Passiflora*, a generic name.

Rods: 0.2 to 0.5 by 1.2 to 3.2 microns. Motile with 1 to 5 polar flagella. Capsules present. Gram-negative.

Gelatin: Liquefied.

Beef-peptone agar colonies: Small, flat, smooth, dry, shining, translucent, grayish and butyrous.

Broth: Turbid in 4 days. Transient pellicle.

Milk: Slightly alkaline. No coagulation nor clearing.

Nitrites not produced from nitrates. No growth on synthetic nitrate agar.

Indole not formed.

Hydrogen sulfide not formed.

Acid reaction occurs in galactose, starch and sucrose. No gas.

Starch is not hydrolysed.

Source: From diseased leaves and fruit of the passion-fruit in New Zealand.

Habitat: Pathogenic on *Passiflora edulis*.

130. **Pseudomonas fabae** (Yu) *comb. nov.* (*Phytomonas fabae* Yu, Bull. of the Chinese Bot. Soc., *2*, 1936, 34.) From Latin, *faba* bean.

Rods: 0.8 to 1.1 by 1.1 to 2.8 microns. Motile with 1 to 4 polar flagella. Gram-negative.

Gelatin: Liquefied.

Nutrient agar colonies: Circular, entire, viscid, glistening, raised, smooth to wrinkled, white to salmon. Medium amber.

Broth: Turbid after 12 hours. Pellicle.

Milk: Growth slow. Clears.

Nitrites produced from nitrates.

Indole production slight.

Hydrogen sulfide not produced.

Acid but not gas from glucose. No acid nor gas developed from arabinose, xylose, fructose, galactose, sucrose, lactose, maltose, raffinose, dextrin, inulin, mannitol or adonitol in a 1 per cent Bacto-peptone broth.

Starch: Very weak diastatic action.

Optimum temperature 35°C. Maximum 37 to 38°C. Minimum 4°C. Thermal death point 52 to 53°C.

Aerobic.

Growth retarded in 2 per cent salt. Very slight growth in 3 per cent salt.

Source: From diseased broad beans at Nanking, China.

Habitat: Pathogenic on broad or Windsor bean, *Vicia faba*.

131. **Pseudomonas astragali** (Takimoto) *comb. nov.* (*Bacterium astragali* Takimoto, Jour. Plant Protect., *17*, 1930, 732; *Phytomonas astragali* Burkholder, in Manual, 5th ed., 1939, 197.) From M. L. *Astragalus*, a generic name.

Description translated by Dr. K. Togashi.

Rods: 0.7 to 0.8 by 1.2 to 2.2 microns. Motile, with 1 or 2 flagella. Gram-negative.

Gelatin: Liquefied.

Agar plates: Growth somewhat slow, colorless or grayish-white, entire margins, more or less aqueous, butyrous.

Uschinsky's medium: Growth vigorous, turbid, not viscid, ring, and sediment.

Milk: No coagulation of casein, slow digestion. Alkaline.

Nitrites not produced from nitrates.

Indole not formed.

Hydrogen sulfide produced in small amount.

No acid or gas from glucose, sucrose, lactose and glycerol in broth.

Starch not hydrolyzed.

Temperature relations: Minimum below 5° and maximum 33°C. Thermal death point 50° to 51°C.

Aerobic.

Source: Species isolated from *Astragalus sp.*

Habitat: Causes a black leaf-spot of *Astragalus sp.*

132. **Pseudomonas columae** (Thornberry and Anderson) *comb. nov.* (*Phytomonas columae* Thornberry and Anderson, Phytopath., *27*, 1937, 948.) From the species, *Corylus colurna*.

Rods: 0.8 to 1.0 by 1.0 to 1.8 microns. Single, in pairs or chains. Capsules. Motile with 1 to 2 polar flagella. Gram-negative.

Gelatin: Liquified.

Glucose agar slants: Growth filiform, raised, dull, smooth, opaque and viscid.

Broth: Moderate turbidity. Ring.

Milk: Peptonization complete with acid production. No reduction of litmus nor coagulation.

Nitrites not produced from nitrates.

Indole not produced.

Hydrogen sulfide not produced.

No appreciable amount of gas from xylose, glucose, sucrose or glycerol.

Starch hydrolyzed.

Optimum temperature 21°C. Minimum 5°C. Maximum 35°C. Thermal death point 50°C.

Aerobic.

Source: From leaves and young stems of the Turkish hazelnut in Illinois.

Habitat: Pathogenic on the Turkish hazelnut, *Corylus colurna*.

133. **Pseudomonas maublancii** (Foex and Lansade) *comb. nov.* (*Bacterium maublancii* Foex and Lansade, Comp. rend. Acad. Sci. Paris, *202*, 1936, 2174; *Phytomonas maublancii* Burkholder, in Manual, 5th ed., 1939, 198.) Named for M. Maublanc, French colonial plant pathologist.

Rods: 0.4 by 1.3 microns. Motile with 1 to 3 polar flagella. Gram-negative.

Gelatin: Liquefied.

Gelatin colonies: Round, translucent, margins entire.

Broth: Thin pellicle.

Milk: Not coagulated; clears.

Nitrites not produced from nitrates.

Indole not formed.

No H_2S formed.

Carbohydrates not fermented.

Ammonia produced.

Growth in Fermi's solution, not in Uschinsky's solution.

Source: Isolated from rotting vascular and parenchymatic tissue of banana stalks.

Habitat: Causes a disease of the banana plant.

134. **Pseudomonas polygoni** (Thornberry and Anderson) *comb. nov.* (*Phytomonas polygoni* Thornberry and Anderson, Phytopath., *27*, 1937, 947.) From Gr. *polygonum*, knot-weed; M. L. *Polygonum*, a generic name.

Rods: 0.5 to 1.5 by 1.5 to 2.5 microns. Motile with 2 to 8 bi-polar flagella. Capsules. Gram-positive (?). Other species reported by these investigators as Gram-positive have proved to be Gram-negative on a retest (Burkholder).

Gelatin: Liquified. Brown.

Glucose agar slant: Abundant, filiform, flat, dull, smooth, pale olive-gray, butyrous. Medium turns brown.

Broth: Turbid. Pellicle.

Milk: Alkaline and clears. Litmus not reduced.

Nitrites not produced from nitrates.

Indole not formed.

Hydrogen sulfide not produced.

No appreciable amount of gas from carbohydrates.

Starch: No hydrolysis.

Optimum temperatures 18°C. Minimum 7°C. Maximum 35°C.

Aerobic.

Source: From diseased leaves of *Polygonum convolvulus* in Illinois.

Habitat: Pathogenic on black bindweed, *Polygonum convolvulus*.

135. **Pseudomonas iridicola** (Takimoto) Stapp. (*Bacterium iridicola* Takimoto, Fungi, Nippon Fungological Soc., *1*, 1931, 24; Stapp, Bot. Rev., *1*, 1935, 408; *Phytomonas iridicola* Burkholder, in Manual, 5th ed., 1939, 198.) From Gr. *iris* (*iridis*), iris, a rainbow; *-cola*, dweller.

Rods: 0.7 to 0.8 by 1.2 to 2 microns. Motile with 1 to 3 polar flagella. Gram-negative.

Gelatin: Liquefied.

Beef agar colonies: White, circular, raised or convex.

Milk: Clears without coagulation.

No acid or gas from carbohydrates.

Starch digested.

Optimum temperature 38°C. Minimum 4°C.

Source: Isolated from a brown leaf spot of iris.

Habitat: Pathogenic on *Iris tectorum* and *Iris japonica*.

136. **Pseudomonas levistici** Osterwalder. (Osterwalder, Cent. f. Bakt., II Abt., *25*, 1909, 260; *Bacterium levistici* Stevenson, Foreign Plant Dis., U. S. Dept. Agr., Office of Sec'y., 1926, 101; *Phytomonas levistici* Magrou, in Hauduroy et al., Dict. d. Bact. Path., Paris, 1937, 373.) From M. L. *Levisticum*, a generic name.

Rods: 0.5 to 0.7 by 1.1 to 1.5 microns. Motile with a polar flagellum. Gram-negative.

Gelatin: Colonies greenish-white. Liquefaction.

Nutrient agar: Good growth at room temperature. Yellowish-white.

Broth: Pellicle.

Indole formed.

No H_2S produced.

Source: Isolated from spots on the leaves of lovage.

Habitat: Pathogenic on lovage, *Levisticum officinale*.

137. **Pseudomonas radiciperda** (Javoronkova) Stapp. (*Bacterium radiciperda* Javoronkova, Bull. Plant Protect., Leningrad, Ser. II, *5*, no. 1, 1932, 161; Stapp, Bot. Rev., *1*, 1935, 408; *Phytomonas radiciperda* Magrou, in Hauduroy et al., Dict. d. Bact. Path., 1937, 401.) From L. *radix* (*radicis*), root; *perdo*, to destroy.

Description from Javoronkova, Rev. App. Myc., *11*, 1932, 652.

Rods: 0.8 by 1 to 2 microns. Capsules. Motile with 1 or 2 polar flagella. Gram-negative.

Gelatin: Liquefaction.

Beef-peptone agar colonies: Round, smooth, shining, white to pale yellow.

Milk: Peptonized.

Indole not formed.

No H_2S formed.

Acid but not gas from carbohydrates.

Optimum temperature 23° to 25°C.

Aerobic.

Habitat: Causes a root rot of red clover (*Trifolium pratense*), lentils (*Lens esculenta*) and lucerne.

138. **Pseudomonas melophthora** Allen and Riker. (Allen and Riker, Phytopath., *22*, 1932, 557; *Bacterium melophthorum* Allen and Riker, *ibid.*; *Phytomonas melophthora* Allen and Riker, *ibid.*) From Gr. *melum*, apple; *phthora*, destroyer.

Rods: 0.68 by 1.32 microns. Motile with 2 polar flagella. Gram-negative; Gram-positive cells appear in old cultures.

Gelatin: No liquefaction.

Nutrient agar plus 2 per cent glucose: Colonies appear in 36 hours. After 3 days colonies circular, smooth, glistening, convex; edges entire; light pink, but not constant.

Broth: Good growth. Pellicle and sediment.

Milk: Little change, if any.

Nitrites not produced from nitrates.

Indole not formed.

No H_2S produced.

Acid from arabinose, glucose, galactose, fructose, sucrose and glycerol. No acid from lactose, maltose, dextrin and inulin.

Starch not hydrolyzed.

Optimum temperature 21° to 25°C.

Source: Description based on 7 cultures isolated from rotting apples and from apple maggots.

Habitat: Pathogenic on apples, and found with the apple maggot, *Rhagoletis pomonella*.

139. **Pseudomonas helianthi** (Kawamura) *comb. nov.* (*Bacterium helianthi* Kawamura, Ann. Phyt. Soc. Japan, *4*, 1934, 27; *Phytomonas helianthi* Magrou, in Hauduroy et al., Dict. d. Bact. Path., Paris, 1937, 362.) From M. L. *Helianthus*, a generic name.

Probable synonym: *Phytomonas helianthi* var. *tuberosi* Thornberry and Anderson, Phytopath., *27*, 1937, 948.

Rods: 1 to 1.4 by 1.6 to 2.4 microns. Motile with a single polar flagellum. Gram-negative.

Gelatin: No liquefaction.

Beef agar colonies: White, circular, edges entire.

Broth: Turbid. Pellicle.

Milk: Peptonized. Litmus reduced.

Nitrates: Gas production.

Indole not produced.

No H_2S produced.

Acid but not gas from sucrose and glycerol. No acid from lactose and maltose.

Starch hydrolyzed.

Optimum temperature 27° to 28°C. Maximum 35.5°C. Minimum 12°C.

Good growth at pH 6.4. No growth pH 5.4 and pH 8.8.

Habitat: Pathogenic on sunflower, *Helianthus debilis*.

140. **Pseudomonas alboprecipitans** Rosen. (Rosen, Ann. Missouri Bot.

Garden, *9*, 1922, 383; *Bacterium albo-precipitans* Elliott, Bact. Plant Path., 1930, 89; *Phytomonas albopre cipitans* Bergey et al., Manual, 3rd ed., 1930, 277.) From Latin *albus*, white and *precipitans*, precipitating, referring to the white precipitate produced in culture.

Rods: 0.6 by 1.8 microns, occurring singly or in pairs. Capsules present. Motile with a polar flagellum. Gram-negative.

Gelatin: Not liquefied.

Nutrient agar colonies: White, circular, raised, smooth, sticky, with margins entire. Whitish discoloration of the medium.

Broth: Turbid in 24 hours. Heavy sediment in old cultures.

Milk: Becomes alkaline and slowly clears.

Nitrites produced from nitrates.

Indole not produced.

No H_2S produced.

Acid but not gas from glucose, fructose, glycerol and mannitol. No acid from lactose, maltose or sucrose.

Starch is hydrolyzed.

Optimum temperature 30° to 35°C. Maximum temperature 40°C. Minimum 0°C.

Aerobic.

Distinctive characteristics: White precipitate in culture media.

Source: Isolated a number of times from foxtail grass.

Habitat: Pathogenic on foxtail, *Chaetochloa lutescens* and other grasses.

141. **Pseudomonas petasitis** (Takimoto) *comb. nov.* (*Bacterium petasitis* Takimoto, Ann. Phyt. Soc. Japan, *2*, 1927, 55; *Phytomonas petasitis* Magrou, in Hauduroy et al., Dict. d. Bact. Path., Paris, 1937, 393.) From M. L. *Petasites*, a generic name.

Rods: 0.8 to 1.1 by 1.1 to 1.7 microns. Motile with a polar flagellum. Gram-negative.

Gelatin: No liquefaction.

Beef agar colonies: White, circular or ameboid, butyrous.

Broth: Strong turbidity. Pellicle.

Milk: Coagulated in 30 days.

Nitrites produced from nitrates with gas formation.

Indole not produced.

No H_2S produced.

No evident acid in peptone broth but gas from glucose, lactose and sucrose. Acid but not gas from glycerol.

Weak growth in broth plus 6 per cent salt.

Optimum temperature 27° to 30°C. Maximum 47°C. Minimum approximately 5°C.

Source: Isolated from brown to black lesions on *Petasites japonicus* in Japan.

Habitat: Pathogenic on leaves of *Petasites japonicus*.

142. **Pseudomonas lignicola** Westerdijk and Buisman. (De Iepenziekte, Arnhem, 1929, 51.) From Latin, *lignum*, wood; *-cola*, dweller.

Rods: Single or short chains. Motile with 1 to several polar flagella. Gram-negative.

Gelatin: No liquefaction.

Malt agar streaks: Milk white with a colorless edge.

Broth: Turbid with light pellicle.

Milk: No coagulation. No acid.

Nitrites not produced from nitrates.

Indole not formed.

Starch hydrolysis slight.

Optimum temperature ±25°C.

Source: From vessels of elm wood showing dark discoloration, in Holland.

Habitat: Pathogenic in elm wood.

143. **Pseudomonas andropogoni** (Erw. Smith) Stapp. (*Bacterium andropogoni* Erw. Smith, Bacteria in Relation to Plant Diseases, *2*, 1911, 63; Elliott and Smith, Jour. Agr. Res., *38*, 1929, 4; Stapp, in Sorauer, Handbuch der Pflanzenkrankheiten, *2*, 5 Auf., 1928, 27; *Phytomonas andropogoni* Bergey et al., Manual, 3rd ed., 1930, 276.) From M.

L. *Andropogon*, a generic name (a synonym of *Holcus*).

Description from Elliott and Smith (*loc. cit.*).

Rods: 0.64 by 1.76 microns. Motile with one to several bipolar flagella. Capsules. Gram-negative.

Gelatin: Feeble liquefaction or none.

Beef-extract agar colonies: Slow-growing, round, smooth, glistening, viscid, white.

Broth: Growth slow with moderate turbidity in 48 hours. A thin pellicle.

Milk: Alkaline and clears.

Nitrites not produced from nitrates.

Indole not formed.

No H_2S formed.

Not lipolytic (Starr and Burkholder, Phytopath., *32*, 1942, 601).

Acid but not gas from glucose, arabinose, fructose and xylose. No acid from sucrose, maltose, lactose, raffinose, glycerol and mannitol.

Starch partially digested.

Optimum temperature 22° to 30°C. Maximum 37° to 38°C. Minimum 1.5°C.

Optimum pH 6.0 to 6.6. Maximum 8.3 to 8.6. Minimum 5.0.

Source: Elliott used for her description 4 cultures isolated from lesions on sorgo, sorghum and broom-corn.

Habitat: Pathogenic on sorghum, *Holcus sorghum*.

144. **Pseudomonas woodsii** (Smith) Stevens. (*Bacterium woodsii* Erw. Smith, Bact. in Relation to Plant Diseases, *2*, 1911, 62; Stevens, Plant Disease Fungi, New York, 1925, 39; *Phytomonas woodsii* Bergey et al., Manual, 3rd ed., 1930, 256.) Named for A. F. Woods, American plant pathologist.

Description from Burkholder and Guterman, Phytopath., *25*, 1935, 118.

Rods: 0.67 by 1.56 microns. Motile with a polar flagellum. Gram-negative.

Gelatin: No liquefaction.

Beef-extract agar slants: Growth slow and scant, filiform, creamy, butyrous.

Broth: Turbid.

Milk: Becomes alkaline but otherwise little changed.

Nitrites not produced from nitrates.

Indole not formed.

No H_2S formed.

Not lipolytic (Starr and Burkholder, Phytopath., *32*, 1942, 601).

Acid but not gas from glucose, fructose, galactose, arabinose, xylose, rhamnose, lactose, glycerol and mannitol. Alkaline reaction from salts of acetic, citric, malic and succinic acids. Sucrose, maltose, salicin, and lactic and formic acids not fermented. Starch not hydrolyzed.

Slight growth in broth plus 3 per cent salt.

Aerobic.

Source: Isolated from water-soaked lesions on carnation leaves.

Habitat: Pathogenic on carnation, *Dianthus caryophyllus*.

145. **Pseudomonas panici-miliacei** (Ikata and Yamauchi) *comb. nov.* (*Bacterium panici-miliacei* Ikata and Yamauchi, Jour. Plant Protect., *18*, 1931, 35; *Phytomonas panici-miliacei* Burkholder, in Manual, 5th ed., 1939, 204.) From M. L. *Panicum miliaceum*.

Description translated by Dr. K. Togashi.

Rods: 0.8 to 1.1 by 1.8 to 2.6 microns. Motile, with a single flagellum. Gram-negative.

Gelatin: Not liquefied.

Potato-agar plates: Growth moderate, whitish, then tinged with light orange, undulating margins.

Broth: Turbid, white pellicle formed.

Milk: No coagulation and slow digestion. Alkaline.

Nitrites are produced from nitrates.

Indole not formed.

No H_2S produced.

No acid and no gas from sucrose, glucose, lactose, glycerol and sodium nitrate.

Starch not hydrolyzed.

Optimum temperature 30° to 35°C.

Facultative anaerobe.

Source: Species first isolated from millet, *Panicum miliaceum*.

Habitat: Causes a leaf stripe of *Panicum miliaceum*.

146. **Pseudomonas saliciperda** Lindeijer. (Lindeijer, Inaug. Diss., Univ. Amsterdam, 1932; Phytopath. Ztschr., *6*, 1933, 373; *Bacterium saliciperda* Burgwitz, Phytopathogenic Bacteria, Leningrad, 1935, 106; *Phytomonas saliciperda* Magrou, in Hauduroy et al., Dict. d. Bact. Path., Paris, 1937, 408.) From L. *salix* (*salicis*), willow; *perdo*, to destroy.

Rods: 1.2 to 2.1 microns in length. Motile with a polar flagellum. Gram-negative.

Gelatin: No liquefaction.

Beef wort agar colonies: Gray-white.

Milk: No acid nor coagulation.

Nitrites produced (small amount) from nitrates.

Indole formation slight.

No gas from carbohydrates.

Starch not hydrolyzed.

Facultative anaerobe.

Source: Isolated from wilted branches of willow and pathogenicity proved.

Habitat: Pathogenic on willow, *Salix spp.*

147. **Pseudomonas eriobotryae** (Takimoto) Dowson. (*Bacterium eriobotryae* Takimoto, Jour. Plant Protect., *18*, 1931, 354; *Phytomonas eriobotryae* Burkholder, in Manual, 5th ed., 1939, 205; Dowson, Trans. Brit. Mycol. Soc., *26*, 1943, 10.) From M. L. *Eriobotrya*, a generic name.

Translated by Dr. K. Togashi.

Rods: 0.7 to 0.9 by 2.2 to 3.0 microns. Motile, with 1 or 2 flagella. Gram-negative.

Gelatin: Not liquefied.

Agar-plates: Colonies appear after 3 days, white or hyaline, butyrous, margins entire.

Broth: Moderately turbid, pellicle powdery, ring formed.

Milk: No coagulation, peptonized slowly. Alkaline.

Nitrites not produced from nitrates.

Indole not formed.

No H_2S produced.

No acid or gas from glucose, sucrose, lactose and glycerol in broth.

Starch not hydrolyzed.

Temperature relations: Minimum below 4°C, optimum 25° to 26°C, and maximum 32°C. Thermal death point 51°C.

Aerobic.

Source: Species isolated from loquat, *Eriobotrya japonica*.

Habitat: Causes a bud rot of *Eriobotrya japonica*.

148. **Pseudomonas wieringae** (Elliott) *comb. nov.* (*Phytomonas betae* Wieringa, Nederl. Tijdschr. Hyg., Microbiol. en Serol., Leiden, *2*, 1927, 148; *Bacterium wieringae* Elliott, Man. Bact. Plant Pathogens, 1930, 264; *Phytomonas wieringae* Burkholder, in Manual, 5th ed., 1939, 206.) Named for K. L. Wieringa, plant pathologist of Holland.

Because *Bacterium betae* Chester (Ann. Rept. Del. Col. Agr. Exp. Sta., *9*, 1897, 53) may be a pseudomonad, the species name proposed by Elliott has been retained.

Description from Elliott (*loc. cit.*).

Rods: 0.5 to 2.0 microns. Motile with 1 to 5 polar flagella. Gram-negative.

Beef-agar colonies: Smooth, round, white to grayish, fluorescent.

Milk: Cleared in 5 days. Not coagulated.

Nitrites not produced from nitrates.

No gas from sugars.

Optimum temperature 28° to 30°C. Maximum 37°C. Minimum 4°C.

Source: Isolated from vascular rot of beets in Holland.

Habitat: Pathogenic on beets, *Beta vulgaris*.

Appendix I*: The following species are believed to belong in the genus *Pseudomonas* although descriptions are frequently incomplete.

Achromobacter pellucidum Harrison. (Canadian Jour. Res., *1*, 1929, 236.) Isolated from halibut. For a description of this species, see Bergey et al., Manual, 5th ed., 1939, 619.

Bacillus aurantiacus tingitanus Remlinger and Bailly. (Maroc Medical, No. 150, 1935; See Lasseur, Dupaix and Babou, Trav. Lab. Microbiol. Fac. Pharm. Nancy, Fasc. 8, 1935, 41.) From water. Dissociates readily. Related to *Pseudomonas fluorescens aureus* Zimmermann. See p. 645.

Bacillus cyaneofluorescens Zangemeister. (Cent. f. Bakt., I Abt., *18*, 1895, 321; *Pseudomonas cyaneofluorescens* Migula, Syst. d. Bakt., *2*, 1900, 906.) From blue milk.

Bacillus fluorescens nivalis Eisenberg. (Eine Gletscherbakterie, Schmelck, Cent. f. Bakt., *4*, 1888, 545; Eisenberg, Bakt. Diag., 3 Aufl., 1891, 77.) From the melting snow of a glacier. Probably a synonym of *Pseudomonas fluorescens*.

Bacillus lactis saponacei Weigmann and Zirn. (Cent. f. Bakt., *15*, 1894, 468.) From soapy milk.

Bacterium auxinophilum Jacobs. (Ann. Appl. Biol., *22*, 1935, 619.) A Gram-negative organism with a polar flagellum which liquefies gelatin rapidly.

Bacterium bosporum Kalniņš. (Latvijas Ūniversitātes Raksti, Serija I, No. 11, 1930, 259.) Decomposes cellulose. Single polar flagellum. From soil.

Bacterium briosii Pavarino. (Atti Ist. Bot. d. R. Univ. di Pavia, Ser. 2, *12*, 1910, 337.) The natural host is *Lycopersicon esculentum*. Pavarino (Rev. di Patol. Veg., *6*, 1913, 161) states that this organism and *Phytobacter lycopersicum* Groenewege (Meded. Rijks. Hoogere Land, Tuin- en Boschbouwschool, Dell 5, *5*, 1912, 217) should be considered identical. It closely resembles *Bacterium vesicatorium* Doidge (Jour. Dept. Agr. So. Africa, *1*, 1920, 718) according to Gardner and Kendrick (Jour. Agr. Res., *21*, 1921, 140).

Bacterium elaphorum Kalniņš. (Latvijas Ūniversitātes Raksti, Serija I, No. 11, 1930, 257.) Decomposes cellulose. Single polar flagellum. From soil.

Bacterium fraenkelii Hashimoto. (Zeit. f. Hyg., *31*, 1899, 88.) A pleomorphic polar flagellate bacterium. From milk.

Bacterium gummis Comes. (Comes, Napoli, Maggio 18, 1884, 14; see Comes, Atti d. R. Ist. d'incoraggiamento alli Sc., Ser. 3, *3*, 1884, 4; *Bacillus gummis* Trevisan, I generi e le specie delle Batteriacee, Milano, 1889, 17.) Pathogenic on grapes, *Vitis spp.*

Bacterium krameriani Pavarino. (Atti R. Accad. Naz. Lincei Rend. Cl. Sci. Fis., Mat. et Nat., *20*, 1911, 233.) Pathogenic on the orchid, *Oncidium krameriani*.

Bacterium pusiolum Kalniņš. (Latvijas Ūniversitātes Raksti, Serija I, No. 11, 1930, 261.) Decomposes cellulose. Single polar flagellum. From manure.

Bacterium protozoides Kalniņš. (Latvijas Ūniversitātes Raksti, Serija I, No. 11, 1930, 263.) Decomposes cellulose. Single polar flagellum. From soil.

Pseudomonas acuta Migula. (Culture No. 11, Lembke, Arch. f. Hyg., *29*, 1897, 317; Migula, Syst. d. Bakt., *2*, 1900, 921.) From the intestine.

Pseudomonas alba Migula. (*Bacillus fluorescens albus* Zimmermann, Bakt. unserer Trink- u. Nutzwässer, I Reihe, 1890, 18; Migula, Syst. d. Bakt., *2*, 1900, 909.) From water. *Bacillus fluorescens non liquefaciens* Eisenberg, Bakt. Diag., 3 Aufl., 1891, 145 may be identical according to Migula (*loc. cit.*).

Pseudomonas allii (Griffiths) Migula. (*Bacterium allium* Griffiths, Proc. Roy. Soc. Edinburgh, *51*, 1887, 40; Migula,

* Appendixes I and II prepared by Prof. Robert S. Breed, New York State Experiment Station, Geneva, New York, July, 1943.

Syst. d. Bakt., *2*, 1900, 932.) From rotted onions.

Pseudomonas aquatilis Migula. (Tataroff, Inaug. Diss., Dorpat, 1891, 31; Migula, Syst. d. Bakt., *2*, 1900, 933.) From water. Said to form spores.

Pseudomonas aromatica Migula. (*Bacillus crassus aromaticus* Tataroff, Inaug. Diss., Dorpat, 1891, 27; Migula, Syst. d. Bakt., *2*, 1900, 880.) From water.

Pseudomonas aromatica var. *quercitopyrogallica* Kluyver, Hof and Boezaardt. (Enzymologia, *7* 1939, 28.)

Pseudomonas articulata Kern. (Arb. bakt. Inst. Karlsruhe, *1*, Heft 4, 1896, 462.) From the stomachs of birds.

Pseudomonas aucubicola Trapp. (Phytopath., *26*, 1936, 264.) Isolated from *Aucuba japonica*. Not pathogenic.

Pseudomonas aurea Migula. (*Bacillus fluorescens aureus* Zimmermann, Bakt. unserer Trink- u. Nutzwässer, I Reihe, 1890, 14; Migula, Syst. d. Bakt., *2*, 1900, 931.) From water.

Pseudomonas brassicae acidae Gruber. (Cent. f. Bakt., II Abt., *22*, 1909, 558). From sauerkraut. Identical with *Bacterium brassicae acidae* Conrad (Arch. f. Hyg., *29*, 1897, 75) according to Lehmann and Neumann (Bakt. Diag., 5 Aufl., *2* 1912, 380.)

Pseudomonas butyri Migula. (*Bacillus butyri fluorescens* Lafar, Arch. f. Hyg., *13*, 1891, 19; Migula, Syst. d. Bakt., *2*, 1900, 894.) From butter.

Pseudomonas calciphila Molisch. (Cent. f. Bakt., II Abt., *65*, 1925, 136.) From fresh water. Deposits $CaCO_3$.

Pseudomonas calco-acetica Clifton. (Enzymologia, *4*, 1937, 246.)

Pseudomonas capsulata Migula. (Syst. d. Bakt., *2*, 1900, 915; not *Pseudomonas capsulata* Bergey et al., Manual, 1st ed., 1923, 124.) Similar to *Pseudomonas macroselmis* Migula.

Pseudomonas caryocyanea (Dupaix) Beijerinck. (*Bacillus caryocyaneus* Dupaix, Thesis, Univ. of Nancy, 1933, 1; Beijerinck, see Dupaix, *ibid.*, 13; *Bacterium caryocyaneum* Dupaix, *ibid.*, 246.) Isolated from rotten willow wood, from yeast mash and beer-wort. Name appears first as *Bacillus caryocyaneus* on a culture sent by Beijerinck from Delft, Holland to the National Collection of Type Cultures, Lister Institute, London. Regarded by Dupaix as closely related to *Bacillus cyaneo-fluorescens* Zangemeister (Cent. f. Bakt., I Abt., *18*, 1895, 321; *Pseudomonas cyaneo-fluorescens* Migula, Syst. d. Bakt., *2*, 1900, 906); Der blaue Bacillus, Mildenberg (Cent. f. Bakt., II Abt., *56*, 1922, 309; *Pseudomonas mildenbergii* Bergey et al., Manual, 3rd ed., 1930, 172); and *Bacillus pyocyaneus* Gessard (Compt. rend. Acad. Sci. Paris, *94*, 1882, 536).

Pseudomonas catarrhalis Chester. (Bacillus der Hundestaupe, Jess, Cent. f. Bakt., II Abt., *25*, 1899, 541; Chester, Man. Determ. Bact., 1901, 308.) Isolated from catarrh in dogs.

Pseudomonas caviae Scherago. (Jour. Bact., *31*, 1936, 83; Jour. Inf. Dis., *60*, 1937, 245.) Cause of an epizootic septicemia in guinea pigs.

Pseudomonas chlorophaena Migula. (Syst. d. Bakt., *2*, 1900, 899.)

Pseudomonas coccacea Migula. (Culture No. 10, Lembke, Arch. f. Hyg., *29*, 1897, 317; Migula, Syst. d. Bakt., *2*, 1900, 924.) From the intestine.

Pseudomonas cohaerea (sic) (Wright) Chester. (*Bacillus cohaerens* Wright, Mem. Nat. Acad. Sci., *7*, 1895, 464; Chester, Man. Determ. Bact., 1901, 312.) From water.

Pseudomonas coli Migula. (Culture No. 8, Lembke, Arch. f. Hyg., *29*, 1897, 315; Migula, Syst. d. Bakt., *2*, 1900, 920.) From the intestine.

Pseudomonas colloides Migula. (*Bacillus fluorescens putidus colloides* Tataroff, Inaug. Diss., Dorpat, 1891, 40; Migula, Syst. d. Bakt., *2*, 1900, 902.) From water. Said to form spores.

Pseudomonas conradi Lehmann and Neumann. (Bakt. Diag., 5 Aufl., *2*, 1912, 394.) Red pigment.

Pseudomonas delabens (Wright) Chester. (*Bacillus delabens* Wright, Mem. Nat. Acad. Sci., *7*, 1895, 456; Chester, Man. Determ. Bact., 1901, 314.) From water.

Pseudomonas duplex Migula. (Culture No. 7, Lembke, Arch. f. Hyg., *29*, 1897, 314; Migula, Syst. d. Bakt., *2*, 1900, 922.) From the intestine.

Pseudomonas ellipsoidea Migula. (*Bacillus oogenes fluorescens β*, Zörkendörfer, Arch. f. Hyg., *16*, 1893, 393; Migula, Syst. d. Bakt., *2*, 1900, 925.) From hens' eggs.

Pseudomonas ephemerocyanea Fuller and Norman. (Jour. Bact., *46*, 1943, 274.) From soil. Decomposes cellulose.

Pseudomonas erythra Fuller and Norman. (Jour. Bact., *46*, 1943, 276.) From soil. Decomposes cellulose.

Pseudomonas erythrospora (Cohn) Migula. (*Bacillus erythrosporus* Cohn, Beitr. z. Biol. d. Pflanzen, *3*, Heft 1, 1879, 128; Migula, in Engler and Prantl, Die naütrl. Pflanzenfam., *1*, 1a, 1895, 29.) From air, meat infusion and water. Said to form spores.

Pseudomonas fimbriata (Wright) Chester. (*Bacillus fimbriatus* Wright, Mem. Nat. Acad. Sci., *7*, 1895, 463; Chester, Man. Determ. Bact., 1901, 313.) From water.

Pseudomonas fluorescens exitiosus van Hall. (Ztschr. f. Pflanzenkr., *13*, 1903, 132.) Causes soft rot of shoots and bulbs of iris (*Iris spp.*).

Pseudomonas foliacea Chester. (*Bacillus fluorescens foliaceus* Wright, Mem. Nat. Acad. Sci., *7*, 1895, 439; Chester, Man. Determ. Bact., 1901, 324; *Bacillus fluorescens-foliaceus* Chester, *ibid.*) From water. Very similar to *Pseudomonas incognita* Chester.

Pseudomonas gasoformans Migula. (Ein neuer gasbildender *Bacillus*, Gärtner, Cent. f. Bakt., *15*, 1894, 1; Migula, Syst. d. Bakt., *2*, 1900, 883.) Gas bubbles in gelatin stab.

Pseudomonas gracilis Migula. (Syst. d. Bakt., *2*, 1900, 888.) Morphologically like *Pseudomonas fluorescens* Migula.

Pseudomonas granulata Kern. (Arb. bakt. Inst. Karlsruhe, *1*, Heft 4, 1896, 464.) From the stomach and intestine of birds.

Pseudomonas halestorgus Elazari-Volcani. (Ph.D. Thesis, Hebrew Univ., Jerusalem, 1940.) A halophilic pseudomonad from the Dead Sea.

Pseudomonas hydrosulfurea Migula. (*Bacillus oogenes hydrosulfureus β*, Zörkendörfer, Arch. f. Hyg., *16*, 1893, 385; Migula, Syst. d. Bakt., *2*, 1900, 898.) From hens' eggs.

Pseudomonas iridis van Hall. (Van Hall, Thesis, Univ. Amsterdam, 1902 and Ztschr. f. Pflanzenkr., *13*, 1903, 129; *Bacterium iridis* Elliott, Man. Bact. Plant Path., 1930, 142; *Phytomonas iridis* Magrou, in Hauduroy et al., Dict. d. Bact. Path., Paris, 1937, 369.) Causes a rot of bulbs and leaves of iris (*Iris spp.*).

Pseudomonas iris (Frick) Migula. (*Bacillus iris* Frick, Arch. f. path. Anat., *116*, 1889, 292; according to Eisenberg, Bakt. Diag., 3 Aufl., 1891, 148; Migula, Syst. d. Bakt., *2*, 1900, 931.)

Pseudomonas italica (Foà and Chiapella) Reinelt. (Quoted from Lehmann and Neumann, Bakt. Diag., 7 Aufl., *2*, 1927, 367.) Phosphorescent.

Pseudomonas javanica (Eijkmann) Migula. (*Photobacterium javanense* Eijkmann, Geneesk. Tijdschr. v. Nederl.-Indië, *32*, 1892, 109; Abst. in Cent. f. Bakt., *12*, 1892, 656; *Bacillus javaniensis* Dyar, Annals New York Acad. Sci., *8*, 1895, 359; *Bacterium javaniensis* Chester, Man. Determ. Bact., 1901, 170; *Photobacterium javanicum* Lehmann and Neumann, Bakt. Diag., 1 Aufl., *2*, 1896, 199; Migula, Syst. d. Bakt., *2*, 1900, 953.) From sea fish in Java. Blue-green luminescence.

Pseudomonas lactica Weiss. (Arb. bakt. Inst. Karlsruhe, *2*, Heft 3, 1902, 238.) From a vegetable infusion.

Pseudomonas lasia Fuller and Norman.

(Jour. Bact., *46*, 1943, 275.) From soil. Decomposes cellulose.

Pseudomonas lembkei Migula. (Culture No. 12, Lembke, Arch. f. Hyg., *29*, 1897, 318; Migula, Syst. d. Bakt., *2*, 1900, 896.) From the intestine.

Pseudomonas liquefaciens (Tataroff) Migula. (*Bacillus liquefaciens* Tataroff, Inaug. Diss., Dorpat, 1891, 29; Migula, Syst. d. Bakt., *2*, 1900, 876.) From water.

Pseudomonas listeri Weiss. (Arb. bakt. Inst. Karlsruhe, *2*, Heft 3, 1902, 260.) From a vegetable infusion.

Pseudomonas longa Migula. (*Bacillus fluorescens longus* Zimmermann, Bakt. unserer Trink- u. Nutzwässer, I Reihe, 1890, 20; Migula, Syst. d. Bakt., *2*, 1900, 907.) From water.

Pseudomonas macroselmis Migula. (*Bacillus fluorescens putidus* Tataroff, Inaug. Diss., Dorpat, 1891, 42; Migula, in Engler and Prantl, Die natürl. Pflanzenfam., *1*, 1a, 1895, 29.) From water.

Pseudomonas maidis (Eisenberg) Migula. (*Bacillus maidis* Eisenberg, Bakt. Diag., 3 Aufl., 1891, 119; Migula, Syst. d. Bakt., *2*, 1900, 877.) From corn grains soaked in water and from feces of pellagra patients.

Pseudomonas maschekii Migula. (Blaugrüner *Bacillus*, Maschek, Bakt. Untersuch. d. Leitmeritzer Trinkwasser, Jahresber. d. Oberrealschule zu Leitmeritz, 1887; Migula, Syst. d. Bakt. *2*, 1900, 916.) From water.

Pseudomonas melochlora (Winkler and Schrötter) Migula. (*Bacillus melochloros* Winkler and Schrötter, Ein neuer grünen Farbstoff entwickelnder Bacillus, Wien, 1890; Migula, Syst. d. Bakt., *2*, 1900, 893.) From caterpillar feces.

Pseudomonas mesenterica Migula. (*Bacillus fluorescens mesentericus* Tataroff, Inaug. Diss., Dorpat, 1891, 38; Migula, Syst. d. Bakt., *2*, 1900, 903.) From water.

Pseudomonas metalloides Migula. (*Bacillus rosaceus metalloides* Tataroff, Inaug. Diss., Dorpat, 1891, 65; not *Bacterium rosaceus metalloides* Dowdeswell, Ann. de Microgr., *1*, 1888–89, 310, see Heffernan, Cent. f. Bakt., II Abt., *8*, 1902, 689; *Pseudomonas rosacea* Migula, in Engler and Prantl, Die natürl. Pflanzenfam., *1*, 1a, 1895, 29; Migula, Syst. d. Bakt., *2*, 1900, 938.) Single flagellum. Red and yellow-red pigment. From water.

Pseudomonas minutissima Migula. (*Bacillus fluorescens liquefaciens minutissimus* Unna and Tommasoli, Monatsh. f. prakt. Dermat., *8*, 1889, 57; according to Eisenberg, Bakt. Diag., 3 Aufl., 1891, 76; Migula, Syst. d. Bakt., *2*, 1900, 891.) Found on human skin in cases of seborrhoic eczema.

Pseudomonas mobilis Migula. (Culture No. 9, Lembke, Arch. f. Hyg., *29*, 1897, 316; Migula, Syst. d. Bakt., *2*, 1900, 923.) From the intestine.

Pseudomonas monadiformis (Kruse) Chester. (*Bacillus coli mobilis* Messea, Riv. d'Igiene, Rome, 1890; *Bacillus monadiformis* Kruse, in Flügge, Die Mikroorganismen, *2*, 1896, 374; Chester, Man. Determ. Bact., 1901, 308.) From typhoid stools.

Pseudomonas mucidolens Levine and Anderson. (Jour. Bact., *23*, 1932, 337.) Causes musty odors in eggs. Also milk (Olsen and Hammer, Iowa State Coll. Jour. Sci., *9*, 1934, 125).

Pseudomonas mucidolens var. *tarda* Levine and Anderson. (Jour. Bact., *23*, 1932, 337.) Causes musty odors in eggs.

Pseudomonas nexibilis (Wright) Chester. (*Bacillus nexibilis* Wright, Mem. Nat. Acad. Sci., *7*, 1895, 441; Chester, Man. Determ. Bact., 1901, 309.) From water.

Pseudomonas nivalis Szilvinyi. (Cent. f. Bakt., II Abt., *94*, 1936, 216.) A red chromogen isolated from red snow in Austria.

Pseudomonas ochroleuca Migula. (*Bacillus* γ, Zörkendörfer, Arch. f. Hyg., *16*, 1893, 396; Migula, Syst. d. Bakt., *2*, 1900, 897.) From hens' eggs.

Pseudomonas oogenes Migula. (*Bacillus oogenes hydrosulfureus* δ, Zörkendörfer, Arch. f. Hyg., *16*, 1893, 386;

Migula, Syst. d. Bakt., *2*, 1900, 878.) Single flagellum. From hens' eggs.

Pseudomonas ovi Migula. (*Bacillus oogenes fluorescens* ε, Zörkendörfer, Arch. f. Hyg., *16*, 1893, 395; Migula, Syst. d. Bakt., *2*, 1900, 924.) From hens' eggs.

Pseudomonas ovicola Migula. (*Bacillus oogenes fluorescens* γ, Zörkendörfer, Arch. f. Hyg., *16*, 1893, 394; Migula, Syst. d. Bact., *2*, 1900, 925.) From hens' eggs.

Pseudomonas pallescens Migula. (*Bacillus viridis pallescens* Frick, in Virchow, Arch. f. path. Anat., *116*, 1889, 292; according to Eisenberg, Bakt. Diag., 3 Aufl., 1891, 154; Migula, Syst. d. Bakt., *2*, 1900, 927.) Source not given.

Pseudomonas pansinii Migula. (*Bacillus fluorescens non liquefaciens* Pansini, in Virchow, Arch. f. path. Anat., *122*, 1890, 452; Migula, Syst. d. Bakt., *2*, 1900, 926.)

Pseudomonas pelliculosa Migula. (*Bacillus oogenes fluorescens* δ, Zörkendörfer, Arch. f. Hyg., *16*, 1893, 395; Migula, Syst. d. Bakt., *2*, 1900, 926.) From hens' eggs.

Pseudomonas pellucida Kern. (Arb. bakt. Inst. Karlsruhe, *1*, Heft 4, 1896, 465.) From the intestine of birds.

Pseudomonas plehniae Spieckermann and Thienemann. (Arch. f. Hyg., *74*, 1911, 110.) Isolated from carp. Pathogenic for many species of fish.

Pseudomonas plicata (Frankland and Frankland) Migula. (*Bacillus plicatus* Frankland and Frankland, Phil. Trans. Roy Soc. London, *178*, B, 1887, 273; Migula, Syst. d. Bakt., *2*, 1900, 881.) From air.

Pseudomonas pseudotyphosa Migula. (Typhusähnlicher Bacillus, Lustig, Diag. d. Bakt. d. Wassers, 1893, 16; Migula, Syst. d. Bakt., *2*, 1900, 893.) From water.

Pseudomonas pullulans (Wright) Chester. (*Bacillus pullulans* Wright, Mem. Nat. Acad. Sci., *7*, 1894, 445; Chester, Man. Determ. Bact., 1901, 315.) From water.

Pseudomonas protea Frost. (U. S. Public Health Ser., Hyg. Lab. Bull. 66, 1910, 27.) From filtered river water. Can be agglutinated by specific typhoid immune-serum.

Pseudomonas rosea Chester. (*Bacillus roseus vini* Bordas, Joulin and Rackowski, Compt. rend. Acad. Sci. Paris, *126*, 1898, 1550; Chester, Man. Determ. Bact., 1901, 327; not *Pseudomonas rosea* Migula, in Engler and Prantl, Die natürl. Pfllanzenfam., *1*, 1a, 1895, 30.) From wine. Said to form spores.

Pseudomonas (Hydrogenomonas) saccharophila Doudoroff. (Enzymologia, *9*, 1940, 50.) From stagnant water.

Pseudomonas sapolactica (Eichholz) De Rossi. (*Bacterium sapolacticum* Eichholz, Cent. f. Bakt., II Abt., *9*, 1902, 631; De Rossi, Microbiologia Agraria e Technica, Torino, 1927, 693.) Isolated from soapy milk.

Pseudomonas sericea Migula. (Seidenglänzender *Bacillus*, Tataroff, Inaug. Diss., Dorpat, 1891, 26; Migula, Syst d. Bakt., *2*, 1900, 882.)

Pseudomonas tenuis Migula. (*Bacillus fluorescens tenuis* Zimmermann, Bakt. unserer Trink- u. Nutzwässer, I Reihe, 1890, 16; Migula, Syst. d. Bakt., *2*, 1900, 910.) From water.

Pseudomonas trommelschlägel (Ravenel) Chester. (*Bacillus trommelschlägel* Ravenel, Mem. Nat. Acad. Sci., *8*, 1896, 26; Chester, Man. Determ. Bact., 1901, 327.) From soil. Said to form spores.

Pseudomonas undulata Chester. (*Bacillus fluorescens undulatus* Ravenel, Mem. Nat. Acad. Sci., *8*, 1896, 20; Chester, Man. Determ. Bact., 1901, 328.) From soil. Said to form spores.

Pseudomonas virescens (Frick) Migula. (*Bacillus virescens* Frick, Arch. f. path. Anat., *116*, 1889, 292; Migula, Syst. d. Bakt., *2*, 1900, 916.) From green sputum.

Pseudomonas viridans (Symmers) Migula. (*Bacillus viridans* Symmers, Brit. Med. Jour., No. 1615, 1891, 1252; Abst. in Cent. f. Bakt., *12*, 1892, 165; Migula, Syst. d. Bakt., *2*, 1900, 890.) From water.

Pseudomonas viridescens Chester. (*Bacillus viridescens liquefaciens* Ravenel, Mem. Nat. Acad. Sci., *8*, 1896, 24; Chester, Man. Determ. Bact., 1901, 328.) From soil. Said to form spores.

Pseudomonas viridis Migula. (*Bacillis* der grünen Diarrhöe der Kinder, Lesage, Arch. d. Physiol. norm. et path., *20*, 1888, 212; see Eisenberg, Bakt. Diag., 3 Aufl., 1891, 238; Migula, Syst. d. Bakt., *2*, 1900, 886.) From intestine of children.

Pseudomonas weigmanni Migula. (Bakterie IV, Weigmann and Zirn, Cent. f. Bakt., *15*, 1894, 466; Migula, Syst. d. Bakt., *2*, 1900, 892.) From soapy milk.

Pseudomonas zörkendörferi Migula. (*Bacillus oogenes fluorescens* α, Zörkendörfer, Arch. f. Hyg., *16*, 1893, 392; Migula, Syst. d. Bakt., *2*, 1900, 897.) From hens' eggs.

Appendix II: The following polar flagellate organism has been described from activated sludge. H. Winogradsky has also described polar flagellate forms from the same source that form zoogloea (Compt. rend. Acad. Sci. Paris, *200*, 1935, 1887; Ann. Inst. Pasteur, *58*, 1937, 333).

Zoogloea ramigera Kruse *emend.* Butterfield. (Kruse, in Flügge, Die Mikroorganismen, 3 Aufl., *1*, 1896, 68; Butterfield, Public Health Reports, *50*, 1935, 671; Culture No. 50, Wattie, Pub. Health Reports, *57*, 1942, 1519.)

Rods: 1 by 2 to 4 microns, with rounded ends. Non-spore-forming. Capsules present. Motile with a single long polar flagellum. Gram-negative.

Gelatin: No liquefaction.

Grows better in aerated liquid media.

Agar: Scant growth.

Indole not formed.

No H_2S produced.

No acid or gas from carbohydrates.

Nitrites not produced from nitrates.

Optimum pH 7.0 to 7.4.

Optimum temperature 28° to 30°C. Good growth at 20° and at 37°C. Minimum temperature 4°C.

Strict aerobe.

Distinctive character: Oxidizes sewage.

Source: Isolated from activated sludge.

Habitat: Produces zoogloeal masses in activated sludge.

Genus II. Xanthomonas *Dowson**

(*Phytomonas* Bergey et al., Manual, 1st ed., 1923, 174; Dowson, Cent. f. Bakt., II Abt., *100*, 1939, 187.)

Cells usually monotrichous, with yellow, water-insoluble pigment. Proteins are usually readily digested. Milk usually becomes alkaline. Hydrogen sulfide is produced. Asparagin is not sufficient as an only source of carbon and nitrogen. Acid is produced from mono- and disaccharides. Mostly plant pathogens causing necrosis. From Gr. *xanthus*, yellow; *monas*, a unit; M. L. monad.

The type species is *Xanthomonas hyacinthi* (Wakker) Dowson.

Key to the species of genus Xanthomonas.

1. Colonies yellow.
    a. Gelatin liquefied.
        b. Starch hydrolysis feeble.
            c. Nitrites not produced from nitrates.
                1. *Xanthomonas hyacinthi.*
                2. *Xanthomonas pruni.*
                3. *Xanthomonas vitians.*

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* Prepared by Prof. Walter H. Burkholder, Cornell Univ., Ithaca, N. Y., June, 1943.

cc. Nitrites produced from nitrates.

4. *Xanthomonas beticola.*
5. *Xanthomonas lactucae-scariolae.*
6. *Xanthomonas rubrilineans.*

bb. Starch hydrolysis strong.

c. Nitrites not produced from nitrates.

d. No brown pigment in beef-extract agar.

7. *Xanthomonas barbareae.*
8. *Xanthomonas begoniae.*
9. *Xanthomonas campestris.*
9a. *Xanthomonas campestris* var. *armoraciae.*
10. *Xanthomonas citri.*
11. *Xanthomonas corylina.*
12. *Xanthomonas cucurbitae.*
13. *Xanthomonas dieffenbachiae.*
14. *Xanthomonas holcicola.*
15. *Xanthomonas incanae.*
16. *Xanthomonas juglandis.*
17. *Xanthomonas lespedezae.*
18. *Xanthomonas malvacearum.*
19. *Xanthomonas pelargonii.*
20. *Xanthomonas phaseoli.*
20a. *Xanthomonas phaseoli* var. *sojense.*
21. *Xanthomonas plantaginis.*
22. *Xanthomonas ricinicola.*
23a. *Xanthomonas translucens* f. sp. *hordei.*
23b. *Xanthomonas translucens* f. sp. *undulosa.*
23c. *Xanthomonas translucens* f. sp. *secalis.*
23d. *Xanthomonas translucens* f. sp. *hordei-avenae.*
23e. *Xahthomonas translucens* f. sp. *cerealis.*
24. *Xanthomonas vasculorum.*
25. *Xanthomonas vesicatoria.*
25a. *Xanthomonas vesicatoria* var. *raphani.*

dd. Brown pigment produced in beef-extract media.

26. *Xanthomonas nakatae.*
20b. *Xanthomonas phaseoli* var. *fuscans.*

cc. Nitrites produced from nitrates.

27. *Xanthomonas papavericola.*

ccc. Ammonia formed in nitrate media.

28. *Xanthomonas alfalfae.*

bbb. Starch not hydrolyzed.

c. Nitrites produced from nitrates.

29. *Xanthomonas acernae.*

cc. Nitrites not produced from nitrates.

30. *Xanthomonas carotae.*
31. *Xanthomonas hederae.*
32. *Xanthomonas phormicola.*
25. *Xanthomonas vesicatoria.*

ccc. Ammonia formed in nitrate media.

33. *Xanthomonas geranii.*

bbbb. Starch hydrolysis not reported.
c. Nitrites produced from nitrates.
34. *Xanthomonas antirrhini.*
35. *Xanthomonas heterocea.*
cc. Nitrites not produced from nitrates.
36. *Xanthomonas gummisudans.*
37. *Xanthomonas lactucae.*
38. *Xanthomonas nigromaculans.*
aa. Gelatin not liquefied.
b. Starch not hydrolyzed.
39. *Xanthomonas oryzae.*
aaa. Gelatin not reported.
b. Starch hydrolyzed.
40. *Xanthomonas celebensis.*
2. Colonies whitish to cream.
a. Gelatin liquefied.
b. Starch hydrolyzed.
c. Nitrites produced from nitrates.
41. *Xanthomonas panici.*
42. *Xanthomonas proteomaculans.*
43. *Xanthomonas manihotis.*
cc. Nitrites not reported.
44. *Xanthomonas rubrisubalbicans.*
bb. Starch not reported.
45. *Xanthomonas cannae.*
46. *Xanthomonas zingiberi.*
47. *Xanthomonas conjaci.*

1. **Xanthomonas hyacinthi** (Wakker) Dowson. (*Bacterium hyacinthi* Wakker, Botan. Centralblatt, *14*, 1883, 315; *Bacillus hyacinthi* Trevisan, I generi e le specie delle Batteriacee, 1889; 19; *Pseudomonas hyacinthi* Erw. Smith, Bot. Gazette, *24*, 1897, 188; *Phytomonas hyacinthi* Bergey et al., Manual, 1st ed., 1923, 177; Dowson, Cent. f. Bakt., II Abt., *100*, 1939, 188.) From Gr. *hyacinthus*, the hyacinth; M. L. *Hyacinthus*, a generic name.

Description from Smith, Div. Veg. Phys. and Path., U. S. D. A. Bul. *26*, 1901, 40.

Rods: 0.4 to 0.6 by 0.8 to 2 microns. Motile with a polar flagellum. Filaments present. Gram-negative.

Gelatin: Slow liquefaction.

Agar colonies: Circular, flat, moist, shining, bright yellow. Media stained brown.

Milk: Casein is precipitated and digested. Tyrosine crystals produced.

Nitrites not produced from nitrates.

Indole: Slight production.

Hydrogen sulfide is produced.

Acid, no gas, from glucose, fructose, galactose, sucrose and maltose.

Starch: Hydrolysis slight.

Optimum temperature 28° to 30°C. Maximum 34° to 35°C. Minimum 4°C.

Aerobic, with the exception of maltose, where it is facultative anaerobic.

Habitat: Produces a yellow rot of hyacinth bulbs, *Hyacinthus orientalis.*

2. **Xanthomonas pruni** (Erw. Smith) Dowson. (*Pseudomonas pruni* Erw. Smith, Science, N. S. *17*, 1903, 456; *Bacterium pruni* Erw. Smith, Bacteria in Relation to Plant Dis., *1*, 1905, 171; *Bacillus pruni* Holland, Jour. Bact., *5*, 1920, 220; *Phytomonas pruni* Bergey et

al., Manual, 1st ed., 1923, 179; Dowson, Cent. f. Bakt., II Abt., *100*, 1939, 190.) From L. *prunus*, plum; M. L. *Prunus*, a generic name.

Probable synonym: *Phytomonas cerasi wraggi* Sackett, Col. Agr. Exp. Sta. Rept., *38*, 1925, 17; *Pseudomonas cerasi wraggi*, *ibid.*; *Bacterium cerasi wraggi* Elliott, Bact. Plant Pathogens, 1930, 111.

Description from Dunegan, U. S. Dept. Agr., Tech. Bull. 273, 1932, 23.

Rods: 0.2 to 0.4 by 0.8 to 1.0 microns. Capsules. Motile with a polar flagellum. Gram-negative.

Gelatin: Liquefaction.

Beef-extract agar colonies: Yellow, circular, smooth, convex, edges entire.

Broth: Turbid becoming viscid.

Milk: Precipitation of casein and digestion.

Nitrites not produced from nitrates.

Indole not formed.

Hydrogen sulfide not produced. Hydrogen sulfide produced (Burkholder).

Lipolytic (Starr and Burkholder, Phytopath., *32*, 1942, 600).

Acid from arabinose, xylose, glucose, fructose, galactose, mannose, maltose, lactose, sucrose, raffinose, melezitose.

Starch is hydrolyzed (slight).

Aerobic.

Optimum temperature 24° to 29°C. Maximum 37°C.

Source: Smith isolated the pathogen from Japanese plums.

Habitat: Pathogenic on plum (*Prunus salicina*), peach (*P. persica*), apricot (*P. armenicca*), etc.

3. **Xanthomonas vitians** (Brown) Starr and Weiss. (*Bacterium vitians* Brown, Jour. Agr. Res., *13*, 1918, 379; *Phytomonas vitians* Bergey et al., Manual, 1st ed., 1923, 183; *Pseudomonas vitians* Stapp, in Sorauer, Handb. d. Pflanzenkrank., *2*, 5 Aufl., 1928, 287; Starr and Weiss, Phytopath., *33*, 1943, 316.) From Latin, *vitians*, injuring, infecting.

Rods: Motile with bipolar flagella. Gram-negative.

Gelatin: Slow liquefaction.

Beef-extract agar colonies: Circular, smooth, thin, cream to cream-yellow.

Broth: Turbid with yellow ring.

Milk: Clears and turns alkaline.

Nitrites not produced from nitrates.

Indole: Feeble production.

Hydrogen sulfide: Feeble production.

Acid but not gas from glucose.

Starch: Feeble hydrolysis.

Optimum temperature 26° to 28°C. Maximum 35°C. Minimum 0°C.

Aerobic.

Source: Isolated from the stem of diseased lettuce plants from South Carolina.

Habitat: Pathogenic on lettuce, *Lactuca sativa*.

4. **Xanthomonas beticola** (Smith, Brown and Townsend) *comb. nov.* (*Bacterium beticolum* Smith, Brown and Townsend, U. S. Dept. Agr., Bur. Plant Ind., Bul. 213, 1911, 194; *Pseudomonas beticola* Holland, Jour. Bact., *5*, 1920, 224; *Phytomonas beticola* Bergey et al., Manual, 1st ed., 1923, 182.) From Latin, *beta*, beet; *-cola*, dweller.

Description from Brown, Jour. Agr. Res., *37*, 1928, 167, where the species is referred to as *Bacterium beticola* (Smith, Brown and Townsend) Potebnia.

Rods: 0.4 to 0.8 by 0.6 to 2.0 microns. Motile with 1 to 4 polar flagella. Capsules. Gram-variable.

Gelatin: Liquefaction.

Beef-agar slants: Moderate filiform growth, flat, glistening, yellow.

Broth: Turbid, yellow ring, abundant sediment.

Milk: Coagulation and peptonization.

Indole not formed.

Hydrogen sulfide formed.

Nitrites produced from nitrates.

Acid from glucose, sucrose, maltose, mannitol. No acid from lactose.

Starch hydrolysis feeble.

Optimum temperature 29°C. Maximum 39°C. Minimum 1.5°C.

Optimum pH 6.5. Maximum 9.0 to 9.5. Minimum 4.5 to 4.8.

Tolerates salt up to 9 per cent.

Aerobic.

Source: Isolated from galls on sugar beets collected in Colorado, Kansas, and Virginia.

Habitat: Produces gall on sugar beets and on garden beets.

NOTE: It is doubtful whether this species belongs in this genus.

5. **Xanthomonas lactucae-scariolae** (Thornberry and Anderson) *comb. nov.* (*Phytomonas lactucae-scariolae* Thornberry and Anderson, Phytopath., *27*, 1937, 109.) From *Lactuca scariola*, the host.

Rods: 0.5 to 1.0 by 1.0 to 1.5 microns. Motile with 1 or 2 polar flagella. Chains present. Capsules. Gram-negative.

Gelatin: Slow liquefaction.

Glucose agar colonies: Round, entire, finely granular, amber yellow.

Broth: Turbid. No pellicle. A yellow rim.

Milk: Slight acid, and peptonization.

Nitrites are produced from nitrates.

Hydrogen sulfide not formed.

No gas from carbon sources.

Starch: Slight diastatic activity.

Optimum temperature 25°C. Maximum 35°C. Minimum 7°C.

Aerobic.

Source: Isolated from necrotic lesions on wild lettuce.

Habitat: Pathogenic on wild lettuce, *Lactuca scariola*, but not on cultivated lettuce, *Lactuca sativa*.

6. **Xanthomonas rubrilineans** (Lee et al.) Starr and Burkholder. (*Phytomonas rubrilineans* Lee, Purdy, Barnum and Martin, Hawaiian Sugar Planters' Assoc. Bull., 1925, 25; *Pseudomonas rubrilineans* Stapp, in Sorauer, Handb. d. Pflanzenkrank., *2*, 5 Aufl., 1928, 35; *Bacterium rubrilineans* Elliott, Man. Bact. Plant Path., 1930, 195; Starr and Burkholder, Phytopath., *32*, 1942, 600.) From L. *ruber*, red; *lineans*, striping.

Rods: 0.7 by 1.67 microns. Motile with 1 or seldom more polar flagella. Gram-negative.

Gelatin: Liquefaction.

Agar (Beef-extract + glucose) colonies: Small, smooth, glistening, buff to yellow.

Broth: Turbid with pellicle. Sediment.

Milk: Casein precipitated and digested.

Nitrites are produced from nitrates.

Indole not produced.

Hydrogen sulfide not formed.

Not lipolytic (Starr and Burkholder, Phytopath., *32*, 1942, 600).

Acid from glucose, fructose, arabinose, xylose, lactose, sucrose, raffinose and mannitol.

Starch: Slight hydrolysis.

Growth range, pH 5.4 to pH 7.3.

Facultative anaerobe.

Source: Description from 3 cultures isolated from the red stripe lesions in sugar cane.

Habitat: Pathogenic on sugar cane.

7. **Xanthomonas barbareae** Burkholder. (Burkholder, Phytopath., *31*, 1941, 348; *Phytomonas barbareae* Burkholder, *ibid.*) From M. L. *Barbarea*, a generic name.

Rods: 0.4 to 0.95 by 1.0 to 3.15 microns. Motile with a single polar flagellum. Gram-negative.

Gelatin: Liquefaction.

Beef-extract peptone colonies: Circular, yellow, smooth, butyrous, growth moderate.

Potato glucose agar: Growth abundant, pale yellow. Mucoid.

Broth: Turbid, yellow granular ring.

Milk: Soft curd, with clearing and production of tyrosine crystals. Litmus reduced.

Nitrates utilized but no nitrites formed. Asparagine and nitrites not utilized.

Hydrogen sulfide produced.

Indole not formed.

Lipolytic (Starr and Burkholder, *loc. cit.*).

Acid from glucose, galactose, xylose, maltose, sucrose, and glycerol. Alkali

produced from salts of malonic, citric, malic, and succinic acids. Rhamnose, salicin and hippuric acid salts not utilized.

Starch hydrolyzed.

Aerobic.

Distinctive characters: Similar to *Xanthomonas campestris* but does not infect cabbage, cauliflower or horseradish.

Source: From black rot of winter cress, *Barbarea vulgaris*.

Habitat: Pathogenic on leaves and stems of *Barbarea vulgaris*.

8. **Xanthomonas begoniae** (Takimoto) Dowson. (*Bacterium begoniae* Takimoto, Jour. Plant. Protect., *21*, 1934, 262; *Pseudomonas begoniae* Stapp, Arbeiten Biol. Reichsanst. f. Land- und Forstw., *22*, 1938, 392; *Phytomonas begoniae* Burkholder, in Manual, 5th ed., 1939, 162; Dowson, Cent. f. Bakt., II Abt., *100*, 1939, 190.) From M. L. *Begonia*, a generic name.

Probable synonyms: *Bacterium begoniae* Buchwald *nom. nud.*, Gartner-Tidende, *45*, 1933, 1; *Phytomonas flava begoniae* Wieringa, Tidschr. Plantziekt., *41*, 1935, 312; *Bacterium flavozonata* McCulloch, Jour. Agr. Res., *54*, 1937, 859 (*Xanthomonas flavozonatum* Dowson, *loc. cit.*).

Translated by Dr. K. Togashi.

Rods: 0.5 to 0.6 by 1.2 to 2.0 microns. Motile with a polar flagellum. Gram-negative.

Gelatin: No liquefaction. Liquefaction (Wieringa, *loc. cit.*, McCulloch, *loc. cit.*, Dowson, *loc. cit.*, and Stapp, *loc. cit.*).

Potato agar colonies: Circular, convex, smooth, moist, shining, yellow.

Broth: Turbid. Yellow pellicle and precipitation.

Milk: No coagulation. Casein digested Alkaline.

Nitrites not produced from nitrates.

Indole not produced.

Hydrogen sulfide produced.

Lipolytic (Starr and Burkholder, Phytopath., *32*, 1942, 600).

Starch hydrolyzed (Dowson, Jour. Roy. Hort. Soc., *63*, 1938, 289).

No acid or gas in peptone broth from glucose, sucrose, lactose or glycerol. Acid from glucose, sucrose, lactose, mannitol and glycerol in peptone-free medium (McCulloch, *loc. cit.*).

Optimum temperature 27°C. Maximum 37°C. Minimum 1° to 3°C.

Source: Isolated from leaf spot of begonia.

Habitat: Pathogenic on *Begonia spp.*

9. **Xanthomonas campestris** (Pammel) Dowson. (*Bacillus campestris* Pammel, Iowa Agr. Exp. Sta. Bull. 27, 1895, 130; *Pseudomonas campestris* Erw. Smith, Cent. f. Bakt., II Abt., *3*, 1897, 284; *Bacterium campestris* (sic) Chester, Del. Col. Agr. Exp. Sta. Ann. Rept., *9*, 1897, 110; *Phytomonas campestris* Bergey et al., Manual, 1st ed., 1923, 176; Dowson, Cent. f. Bakt., II Abt., *100*, 1939, 190.) From L. *campestris* of the field.

Description from McCulloch (Jour. Agr. Res., *38*, 1929, 278). Species is probably composed of several varieties. See descriptions by Mekta, Ann. Appl. Biol., *12*, 1925, 330; Paine and Nirula, Ann. Appl. Biol., *15*, 1928, 46; Wormald and Frampton, Ann. Rept. East. Mall. Res. Sta., 1926 and 1927, II Supplement, 1928, 108; and others.

Rods: 0.3 to 0.5 by 0.7 to 2.0 microns. Motile with a polar flagellum. Capsules. Gram-negative.

Gelatin: Liquefied.

Beef agar colonies: Wax yellow, round, smooth, shining, translucent, margins entire.

Broth: Turbid with yellow rim and sometimes a pellicle.

Milk: Casein digested with the formation of tyrosine crystals. Alkaline.

Nitrites not produced from nitrates.

Indole formation weak.

Hydrogen sulfide produced.

Lipolytic (Starr and Burkholder, Phytopath., *32*, 1942, 600).

Acid, no gas, from glucose, sucrose, lactose, glycerol and mannitol.

Starch is hydrolyzed.

Optimum temperature 28° to 30°C. Maximum 36°C.

Aerobic.

Distinctive characters: Causes a vascular infection in cabbage, cauliflower and rutabagas.

Source: Pammel (*loc. cit.*) first isolated the pathogen from diseased rutabagas.

Habitat: Pathogenic on cabbage, cauliflower and other related species.

9a. *Xanthomonas campestris* var. *armoraciae* (McCulloch) Burkholder. (*Bacterium campestre* var. *armoraciae* McCulloch, Jour. Agr. Res., *38*, 1929, 269; *Phytomonas campestris* var. *armoraciae* Bergey et al., Manual, 3rd ed., 1930, 251; Burkholder, Phytopath., *32*, 1942, 601.) From Gr. *Armoracia*, the horse radish.

Cultural characters same as *Xanthomonas campestris*.

Distinctive characters: Causes a leaf spot of horse radish. No vascular infection.

Source: Isolated from diseased horseradish leaves collected in Washington, D. C., Virginia, Connecticut, Iowa and Missouri.

Habitat: Pathogenic on horse radish and related species.

10. **Xanthomonas citri** (Hasse) Dowson. (*Pseudomonas citri* Hasse, Jour. Agr. Res., *4*, 1915, 97; *Bacterium citri* Doidge, Union So. Africa, Dept. Agr. Sci. Bul. 8, 1916, 20; *Bacillus citri* Holland, Jour. Bact., *5*, 1920, 218; *Phytomonas citri* Bergey et al., Manual, 1st ed., 1923, 181; Dowson, Cent. f. Bakt., II Abt., *100*, 1939, 190.) From M. L. *Citrus*, a generic name.

Rods: 0.5 to 0.75 by 1.5 to 2 microns, occurring in chains. Motile with a single polar flagellum. Gram-negative.

Gelatin: Liquefied.

Beef agar colonies: Appear in 36–48 hours, circular, smooth, raised, dull yellow.

Broth: Turbid in 24 hours. A yellow ring formed.

Milk: Casein is precipitated.

Nitrites not produced from nitrates.

Hydrogen sulfide produced (Reid, New Zealand Jour. Sci. and Tech., *22*, 1938, 60).

Indole not formed.

No gas from glucose, lactose or mannitol.

Starch hydrolyzed (Reid, *loc. cit.*).

Aerobic.

Optimum temperature, 25° to 34°C. Maximum 38°C. Minimum 10°C. (Okabe, Jour. Soc. Trop. Agr., *4*, 1932, 476).

Source: Isolated from canker on orange.

Habitat: Produces a canker on many species of *Citrus* and related plants.

11. **Xanthomonas corylina** Miller, Bollen, Simmons, Gross, and Barss. (Miller et al., Phytopath., *30*, 1940, 731; *Phytomonas corylina* Miller et al., *ibid.*) From Gr. *corylus*, the hazelnut; M. L. *corylina*, of the hazel nut.

Rods: 0.5 to 0.7 by 1.1 to 3.8 microns. Motile with a polar flagellum. Capsules. Gram-negative.

Gelatin: Liquefaction.

Nutrient glucose-agar streaks: Abundant growth, filiform, convex, glistening, smooth, opaque, pale lemon yellow, viscid.

Broth: Turbid. Ring formed in 2–5 days.

Milk: Enzymatic curd that is slowly digested. Litmus reduced. Crystal formation (Burkholder).

Nitrites not produced from nitrates.

Nitrogen sources utilized are peptone, aspartic acid, alanine, leucine, sodium ammonium phosphate, allantoin, tyrosine, uric acid and brucine.

Indole is not produced.

Hydrogen sulfide not produced on lead acetate agar. H_2S produced after Zobell and Feltham's method (Burkholder).

Selenium dioxide reduced.

Lipolytic (Starr and Burkholder, Phytopath., *32*, 1942, 600).

Acid, no gas from glucose, fructose, galactose, lactose, sucrose, maltose, xylose, raffinose, mannitol, glycerol, and starch. Alkali from salts of citric. lactic,

malic and succinic acids. Arabinose, rhamnose, dulcitol, salicin, inulin, and cellulose not utilized.

Starch is hydrolyzed.

Optimum temperature 28° to 32°C. Maximum 37°C. Minimum 5° to 7°C. Thermal death point 53° to 55°C.

pH range for growth: pH 5.2 to 10.5. Optimum pH 6 to 8.

Strict aerobe.

Distinctive characters: Cultural characters the same or similar to *Xanthomonas juglandis*. The two species do not cross-infect.

Source: 26 isolates from widely scattered filbert orchards in Oregon and Washington.

Habitat: Pathogenic on filberts (*Corylus avellana* and *C. maxima*).

12. **Xanthomonas cucurbitae** (Bryan) Dowson. (*Bacterium cucurbitae* Bryan, Science, *63*, 1926, 165; Bryan, Jour. Agr. Res., *40*, 1930, 389; *Phytomonas cucurbitae* Bergey et al., Manual, 3rd ed., 1930, 251; *Pseudomonas cucurbitae* Stapp, Bot. Rev., *1*, 1935, 408; Dowson, Cent. f. Bakt., II Abt., *100*, 1939, 190.) From L. *curcurbita*, a gourd; M. L. *Cucurbita*, a generic name.

Rods: 0.45 to 0.6 by 0.5 to 1.3 microns. Motile, usually with a single polar flagellum. Gram-negative.

Gelatin: Liquefied.

Beef-agar slants: Growth moderate, mustard yellow, undulating margins, viscid to butyrous.

Broth: Moderately turbid. Ring and yellow sediment.

Milk: Precipitation of casein and digestion. Alkaline.

Nitrites not produced from nitrates.

Indole not formed.

Hydrogen sulfide produced.

Acid from glucose, galactose, fructose, lactose, maltose, sucrose and glycerol. No acid from mannitol.

Starch is hydrolyzed.

Optimum temperature 25° to 30°C. Maximum 35°C.

Optimum pH 6.5 to 7.0. Limits of growth pH 5.8 to 9.0.

Slight growth in 5 per cent salt.

Aerobic.

Source: Species first isolated from squash.

Habitat: Causes a leaf spot of squash and related plants.

13. **Xanthomonas dieffenbachiae** (McCulloch and Pirone) Dowson. (*Phytomonas dieffenbachiae* McCulloch and Pirone, Phytopath., *29*, 1939, 962; *Bacterium dieffenbachiae* McCulloch and Pirone, *ibid.*; Dowson, Trans. Brit. Mycol. Soc., *26*, 1943, 12.) From M. L. *Dieffenbachia*, a generic name.

Rods: 0.3 to 0.4 by 1.0 to 1.5 microns. Motile with a single polar flagellum. Capsules. Gram-negative.

Gelatin: Liquefied.

Beef-infusion peptone agar colonies: Slow growing, circular, flat, smooth, translucent. Butyrous. Massicot to Naples yellow.

Broth: Turbid. Yellow rim or slight pellicle.

Milk: Slow peptonization and formation of tyrosine crystals. Litmus reduced.

Nitrites not formed from nitrates

Indole not produced.

Hydrogen sulfide produced.

Acid from glucose, sucrose, lactose, galactose, fructose and glycerol. Growth but no acid in maltose and mannitol.

Starch moderately hydrolyzed.

Optimum temperature 30° to 31°C. Maximum 37° to 38°C. Minimum 5°C.

Aerobe.

Source: Seven isolates from diseased leaves of *Dieffenbachia picta*.

Habitat: Pathogenic on *Dieffenbachia picta*. Artificial infection of *Dracaena fragrans*.

14. **Xanthomonas holcicola** (Elliott) Starr and Burkholder. (*Bacterium holcicola* Elliott, Jour. Agr. Res., *40*, 1930, 972; *Phytomonas holcicola* Bergey et al., Manual, 4th ed., 1934, 271; *Pseudomonas*

holcicola Stapp, Bot. Rev., *1*, 1935, 407; Starr and Burkholder, Phytopath., *32*, 1942, 600.) From Gr. *holcus*, sorghum, *-cola*, dweller; M. L. *Holcus*, a generic name.

Rods: 0.75 by 1.58 microns. Motile with 1 or 2 polar flagella. Capsules. Gram-negative.

Gelatin: Liquefied.

Beef-infusion peptone agar colonies: Round, umbonate, glistening, smooth, translucent to opaque, wax yellow, butyrous.

Broth: Trace of growth in 24 hours. Later turbid with a slight ring.

Milk: Casein precipitated and peptonized. Alkaline.

Nitrite production doubtful.

Indole not produced.

Hydrogen sulfide is produced.

Lipolytic (Starr and Burkholder, *loc. cit.*).

Acid, no gas, from sucrose.

Starch is hydrolyzed.

Optimum temperature 28° to 30°C. Maximum 36° to 37°C. Minimum 4°C.

Optimum pH 7.0 to 7.5. Growth range pH 5.5 to 9.0.

Source: Isolated from many collections of sorghum leaves showing a streak disease.

Habitat: Pathogenic on leaves of *Holcus sorghum* and *H. halepensis*.

15. **Xanthomonas incanae** (Kendrick and Baker) Starr and Weiss. (*Phytomonas incanae* Kendrick and Baker, California Bull. 665, 1942, 10; Starr and Weiss, Phytopath., *33*, 1943, 316.) From its host plant *Matthiola incana*; L. *incanus*, quite gray or hoary.

Rods: 0.4 to 0.8 by 0.6 to 2.5 microns. Motile with a polar flagellum. Gram-negative.

Gelatin: Liquefied.

Beef extract agar colonies: Round, smooth, convex or pulvinate, glistening, margin entire, picric yellow to amber color.

Broth: Turbid.

Milk: No coagulation. A clearing of the medium.

Nitrites not produced from nitrates.

Indole not formed.

Lipolytic (Starr and Burkholder, Phytopath., *32*, 1942, 600).

Acid but no gas from glucose, lactose, sucrose, mannitol, d-galactose, xylose, d-mannose, raffinose, trehalose, and glycerol. No acid from maltose, l-arabinose, or rhamnose.

Starch not hydrolyzed. Starch hydrolyzed (Burkholder).

Tolerates 3 per cent salt.

Growth in beef broth at pH 4.4.

Aerobic.

Distinctive characters: Causes a disease of flowering stock but not of cabbage. Differs from *Xanthomonas campestris* in that it does not utilize l-arabinose, nor maltose.

Source: Four isolates from diseased plants of *Matthiola incana*.

Habitat: Pathogenic on flowering stocks.

16. **Xanthomonas juglandis** (Pierce) Dowson. (*Pseudomonas juglandis* Pierce, Bot. Gaz., *31*, 1901, 272; *Bacterium juglandis* Erw. Smith, Bacteria in Relation to Plant Dis., *1*, 1905, 171; *Bacillus juglandis* Holland, Jour. Bact., *5*, 1920, 218; *Phytomonas juglandis* Bergey et al., Manual, 3rd ed., 1930, 247; Dowson, Cent. f. Bakt., II Abt., *100*, 1939, 190.) From L. *juglans* (*-andis*), the walnut; M. L. *Juglans*, a generic name.

Description taken from Miller et al., Phytopath., *30*, 1940, 731.

Rods: 0.5 to 0.7 by 1.1 to 3.8 microns. Motile with a polar flagellum. Capsules. Gram-negative.

Gelatin: Liquefaction.

Nutrient glucose-agar streaks: Abundant growth, filiform, convex, glistening, smooth, opaque, pale lemon yellow, viscid.

Broth: Turbid. Ring formed in 2 to 5 days.

Milk: Enzymatic curd that is slowly digested. Litmus reduced. Crystal formation (Burkholder).

Nitrites not produced from nitrates.

Nitrogen sources utilized are peptone, aspartic acid, alanine, leucine, sodium ammonium phosphate, allantoin, tyrosine uric acid and brucine.

Indole is not produced.

Hydrogen sulfide not produced on lead acetate agar. H_2S produced after Zobell and Feltham's method (Burkholder).

Selenium dioxide reduced.

Lipolytic (Starr and Burkholder, Phytopath., *32*, 1942, 600).

Acid, no gas from glucose, fructose, galactose, lactose, sucrose, maltose, xylose, raffinose, mannitol, glycerol, and starch. Alkali from salts of citric, lactic, malic and succinic acid. Arabinose, rhamnose, dulcitol, salicin, inulin, and cellulose not utilized.

Starch is hydrolyzed.

Optimum temperature 28° to 32°C. Maximum 37°C. Minimum 5° to 7°C. Thermal death point 53° to 55°C.

pH range for growth pH 5.2 to 10.5. Optimum pH 6 to 8.

Source: Isolated from black spots on the leaves and nuts of English walnuts, *Juglans regia.*

Habitat: Pathogenic on the walnut, *Juglans spp.*

17. **Xanthomonas lespedezae** (Ayers, Lefebvre and Johnson) *comb. nov.* (*Phytomonas lespedezae* Ayers, Lefebvre and Johnson, U. S. Dept. Agr. Tech. Bul. 704, 1939, 19.) From M. L. *Lespedeza*, a generic name.

Rods: 0.56 by 1.62 microns. Single, in pairs or occasional short chain. Motile with 1 polar flagellum. Gram-negative. Capsules.

Gelatin: Liquefied. Also egg albumin and blood serum.

Nutrient agar colonies: Circular, raised, glistening, translucent, and viscid. Yellow.

Broth: Turbid in 48 hours.

Milk: Peptonized and becomes alkaline.

Nitrites not produced from nitrates.

Indole is produced after 11 days.

Hydrogen sulfide is produced.

No gas in carbohydrates.

Starch hydrolyzed.

Aerobic.

Optimum temperature near 35°C. No growth at 5°C. or at 40°C.

Source: Isolated from diseased *Lespedeza spp.* collected in Virginia, New York and Illinois.

Habitat: Pathogenic on *Lespedeza spp.*

18. **Xanthomonas malvacearum** (Erw. Smith) Dowson. (*Pseudomonas malvacearum* Erw. Smith, U. S. Dept. Agr., Div. Veg. Phys. and Path., Bul. 28, 1901, 153; *Bacterium malvacearum* Erw. Smith, Bact. in Rel. to Plant Diseases, *1*, 1905, 171; *Bacillus malvacearum* Holland, Jour. Bact., *5*, 1920, 219; *Phytomonas malvacearum* Bergey et al., Manual, 1st ed., 1923, 178; Dowson, Cent. f. Bakt., II Abt., *100*, 1939, 190.) From L. *malva*, mallows; M. L. *Malvaceae*, a family name.

Description from Elliott, Man. Bact. Plant Pathogens, 1930, 153; and Lewis, Phytopath., *20*, 1930, 723.

Rods: Motile with one polar flagellum. Gram-negative.

Gelatin: Liquefaction.

Agar slants: Moderate growth, convex, smooth, glistening, pale yellow, wavy to irregular margins.

Broth: Slight to moderate turbidity. Sediment.

Milk: Casein precipitated and slowly digested.

Nitrites not produced from nitrates.

Hydrogen sulfide is produced (Burkholder).

Not lipolytic (Starr and Burkholder, Phytopath., *32*, 1942, 600).

Acid but not gas from glucose, galactose, fructose, xylose, lactose, maltose, sucrose, raffinose, glycerol, inulin and glycogen. Alkaline reaction from salts of acetic, citric, lactic and succinic acids. No fermentation of arabinose, mannitol, dulcitol, salicin, and salts of formic, oxalic and tartaric acids (Lewis, *loc. cit*).

Starch hydrolyzed (Lewis, *loc. cit.*).

Optimum temperature 25° to 30°C. Maximum 36° to 38°C. (Elliott, *loc. cit.*).

Source: Isolated from angular leaf spot of cotton.

Habitat: Pathogenic on cotton wherever it is grown, causing a leaf spot, a stem lesion and a boll lesion.

19. **Xanthomonas pelargonii** (Brown) Starr and Burkholder. (*Bacterium pelargoni* Brown, Jour. Agr. Res., *23*, 1923, 372; *Pseudomonas pelargoni* Stapp, in Sorauer, Handb. d. Pflanzenkrank, *2*, 5 Aufl., 1928, 181; *Phytomonas pelargonii* Bergey et al., Manual, 3rd ed., 1930, 250; Starr and Burkholder, Phytopath., *32*, 1942, 600.) From Greek, *pelargus*, the stork; M. L. *Pelargonium*, a generic name for the stork's bill geranium.

Rods: 0.67 by 1.02 microns. Capsules. Motile with a polar flagellum. Gram-negative.

Gelatin: Slow liquefaction.

Beef-agar colonies: Cream-colored, glistening, round, with delicate internal markings.

Broth: Turbid in 24 hours. Incomplete pellicle.

Milk: Alkaline. Clearing in bands.

Nitrites not produced from nitrates.

Indole formation slight.

Hydrogen sulfide produced.

Lipolytic (Starr and Burkholder, Phytopath., *32*, 1942, 600).

Slight acid but not gas from glucose, sucrose and glycerol.

Starch hydrolysis feebly positive.

Optimum temperature 27°C. Maximum 35°C.

No growth in broth plus 3.5 per cent salt.

Aerobic.

Source: Isolated from spots on leaves of *Pelargonium* from District of Columbia, Maryland and New Jersey.

Habitat: Pathogenic on *Pelargonium spp.* and *Geranium spp.*

20. **Xanthomonas phaseoli** (Erw. Smith) Dowson. (*Bacillus phaseoli* Erw. Smith, Bot. Gaz., *24*, 1897, 192; A. A. A. S. Proc., *46*, 1898, 288; *Pseudomonas phaseoli* Erw. Smith, U. S. Dept. Agr., Div. Veg. Phys. and Path., Bul. 28, 1901, 1; *Bacterium phaseoli* Erw. Smith, Bact. in Rel. to Plant Dis., *1*, 1905, 72; *Phytomonas phaseoli* Bergey et al., Manual, 1st ed., 1923, 177; Dowson, Cent. f. Bakt., II Abt., *100*, 1939, 190.) From Gr. *phaseolus*, the bean; M. L. *Phaseolus*, a generic name.

Description from Burkholder, Cornell Agr. Exp. Sta. Mem. 127, 1930, 18; and Phytopath., *22*, 1932, 609.

Rods: 0.87 by 1.9 microns. Motile with a polar flagellum. Gram-negative.

Gelatin: Liquefaction.

Beef-extract agar colonies: Circular, amber yellow, smooth, butyrous, edges entire.

Broth: Turbid in 24 hours. Yellow ring.

Milk: Casein precipitated and digested. Alkaline. Tyrosine crystals formed.

Nitrites not produced from nitrates.

Indole not formed.

Hydrogen sulfide produced.

Lipolytic (Starr and Burkholder, Phytopath., *32*, 1942, 600).

Acid but not gas from glucose, galactose, fructose, arabinose, xylose, maltose, lactose, sucrose, raffinose and glycerol. Alkaline reaction from salts of acetic, malic, citric and succinic acids. Mannitol, dulcitol, salicin and formic and tartaric acids not fermented.

Starch is hydrolyzed.

Aerobic.

Very slight growth in beef broth plus 4 per cent salt (Hedges, Jour. Agr. Res., *29*, 1924, 243).

Distinctive character: Similar in culture to *Xanthomonas campestris*, *X. juglandis*, *X. vesicatoria*, etc., but they do not cross infect.

Habitat: Pathogenic on the bean (*Phaseolus vulgaris*), the hyacinth bean (*Dolichos lablab*), the lupine (*Lupinus polyphillus*), etc. Not pathogenic on the soy bean (*Glycine sp.*), nor cowpea (*Vigna sp.*).

20a. *Xanthomonas phaseoli* var. *sojensis* (Hedges) Starr and Burkholder. (*Bacterium phaseoli* var. *sojense* Hedges, Science, *56*, 1922, 11; Jour. Agr. Res., *29*, 1924, 229; *Phytomonas phaseoli* var. *sojense* Burkholder, Phytopath., *20*, 1930, 7; Starr and Burkholder, Phytopath., *32*, 1942, 600.) From M. L. the soy bean, *Soja*, a generic name; M. L. *sojensis*, of the soybean.

Synonyms: *Pseudomonas glycines* Nakano, Jour. Plant Protect. Tokyo, *6*, 1919, 39 (*Bacterium glycines* Elliott, Manual Bact. Plant Path., 1928, 133; *Phytomonas glycines* Magrou, in Hauduroy et al., Dict. d. Bact. Path., 1937, 358). (See Takimoto, Jour. Plant Protect. Tokyo, *18*, 1931, 29; and Okabe, Jour. Trop. Agr. Formosa, *4*, 1932, 473.)

Distinctive character: Differs from *Xanthomonas phaseoli* in that it infects the soy bean, *Glycine max*.

Source: Isolated from pustules on the leaves and pods of soy bean, both in America and in Japan.

Habitat: Pathogenic on the soy bean, *Glycine max* and the common bean, *Phaseolus vulgaris*.

20b. *Xanthomonas phaseoli* var. *fuscans* (Burkholder) Starr and Burkholder. (*Phytomonas phaseoli* var. *fuscans* Burkholder, Cornell Agr. Exp. Sta. Mem. 126, 1930, 22; Phytopath., *22*, 1932, 699; *Bacterium phaseoli* var. *fuscans* Okabe, Jour. Soc. Trop. Agr. Formosa, *5*, 1933, 161; *Pseudomonas phaseoli* var. *fuscans* Stapp, Bot. Rev., *1*, 1935, 407; Starr and Burkholder, Phytopath., *32*, 1942, 600.) From L. *fuscans*, producing a brown color.

Distinctive characters: Differs from *Xanthomonas phaseoli* in that it produces a deep brown color in beef-extract-peptone media and in tyrosine media. Action on maltose negative or feeble.

Source: Two cultures isolated; one from a diseased bean leaf (1924) and a diseased pod (1927) collected in Switzerland.

Habitat: Pathogenic on beans, *Phaseolus vulgaris*, and related plants.

21. **Xanthomonas plantaginis** (Thornberry and Anderson) *comb. nov.* (*Phytomonas plantaginis* Thornberry and Anderson, Phytopath., *27*, 1937, 947.) From Latin, *Plantago* (*-aginis*), plantain; M. L. *Plantago*, a generic name.

Rods: 0.6 to 1.0 by 1.0 to 1.8 microns. Occurring singly or in chains. Capsules. Motile with 1 to 2 polar flagella. Gram-negative.

Gelatin: Slight liquefaction.

Glucose agar slant: Growth moderate, filiform, raised, opaque, yellow and viscid.

Broth: Moderately turbid with ring.

Milk: Slight acidity, no reduction of litmus. Peptonization.

Nitrites not produced from nitrates.

Indole not formed.

Hydrogen sulfide not produced.

No appreciable amount of gas from carbohydrates.

Starch is hydrolyzed.

Optimum temperature 25°C. Minimum 12°C. Maximum 35°C. Thermal death point 50°C.

Aerobic.

Source: From diseased leaves of *Plantago lanceolata* in Illinois.

Habitat: Pathogenic on *Plantago spp.*

22. **Xanthomonas ricinicola** (Elliott) Dowson. (*Bacterium ricini* Yoshi and Takimoto, Jour. Plant Protect. Tokyo, *15*, 1928, 12; *Bacterium ricinicola* Elliott, Man. Bact. Plant Path., 1930, 193; *Phytomonas ricinicola* Burkholder, in Manual, 5th ed., 1939, 152; Dowson, Cent. f. Bakt., II Abt., *100*, 1939, 190; *Xanthomonas ricini* Dowson, *ibid.*) From L. living on the castor bean; M. L. *Ricinus*, a generic name.

Rods: 0.4 to 0.9 by 1.3 to 2.6 microns. Capsules. Short chains. Motile with polar flagella. Gram-negative.

Gelatin: Liquefaction.

Nutrient agar colonies: Lemon yellow, changing to brown.

Milk: Slightly acid. No coagulation. Peptonization.

Nitrites not produced from nitrates.

Acid but not gas from lactose.

Starch hydrolyzed.

Optimum temperature 29° to 30°C. Maximum 39°C. Minimum 2.5°C.

Aerobic.

Source: Isolated from leaf-spot of castor-bean.

Habitat: Pathogenic on *Ricinus communis*.

23a. *Xanthomonas translucens* f. sp. *hordei* Hagborg. (Canadian Jour. of Res., *20*, 1942, 317.) From L. *translucens*, shining through, translucent, referring to the character of the lesion produced by this pathogen. Form name from *Hordeum*, a generic name.

Synonyms: *Bacterium translucens* Jones, Johnson and Reddy, Jour. Agr. Res., *11*, 1917, 637; *Pseudomonas translucens*, *ibid.*; *Phytomonas translucens* Bergey et al, Manual, 3rd ed., 1930, 252; *Xanthomonas translucens* Dowson, Cent. f. Bakt., II Abt., *100*, 1939, 190.

Rods: 0.5 to 0.8 by 1 to 2.5 microns. Motile with a single polar flagellum. Gram-negative.

Gelatin: Liquefaction.

Beef-peptone agar colonies: Round, smooth, shining, amorphous except for inconspicuous somewhat irregular concentric striations within, wax-yellow tinged with old gold; margin entire.

Broth: Turbidity becomes rather strong. Pellicle.

Milk: Soft coagulum and digestion. Milk clears. Tyrosine crystals produced.

Nitrites not produced from nitrates.

Indole: Slight formation.

Hydrogen sulfide produced.

Lipolytic (Starr and Burkholder, Phytopath., *32*, 1942, 600).

Ammonia from peptone.

Acid but not gas from glucose, d-fructose, d-mannose, d-galactose, sucrose, lactose, and sometimes salicin. No utilization of l-rhamnose, inositol, maltose, raffinose, inulin, d-mannitol, and dulcitol.

Starch hydrolyzed.

Optimum temperature 26°C. Maximum 36°C. Minimum 6°C.

Aerobic.

Distinctive characters: All forms of *Xanthomonas translucens* have the same cultural characters. They differ mainly in pathogenicity. This form is pathogenic on barley, *Hordeum spp.*; but not on oats, *Avena spp.*, rye, *Secale cereale* nor on wheat, *Triticum spp.*

Source: Isolated from leaves and seed of barley, *Hordeum vulgare*.

Habitat: Occurs naturally on barley.

23b. *Xanthomonas translucens* f. sp. *undulosa* (Smith, Jones and Reddy) Hagborg. (*Bacterium translucens* var. *undulosum* Smith, Jones and Reddy, Science, *50*, 1919, 48; *Pseudomonas translucens* var. *undulosa* Stapp, in Sorauer, Handb. d. Pflanzenk., *2*, 5 Auf., 1928, 17; *Phytomonas translucens* var. *undulosa* Hagborg, Canadian Jour. Res., *14*, 1936, 347; Hagborg, Canadian Jour. Res., *20*, 1942, 317.) From L. *unda*; M.L. *undulosus*, undulate, referring to the undulation of the colony.

Distinctive characters: Cultural characters same as all forms of *Xanthomonas translucens*. Pathogenic on wheat, *Triticium spp.*, barley, *Hordeum spp.* and rye, *Secale cereale* but not on oats, *Avena spp.*

Source: Isolated repeatedly from black chaff of wheat.

Habitat: Usually found on wheat causing the black chaff, and on rye.

23c. *Xanthomonas translucens* f. sp. *secalis* (Reddy, Godkin and Johnson) Hagborg. (*Bacterium translucens* var. *secalis* Reddy, Godkin and Johnson, Jour. Agr. Res., *28*, 1924, 1039; *Pseudomona translucens* var. *secalis* Stapp, in Sorauer, Handb. d. Pflanzenkr., *2*, 5 Aufl., 1928, 24; *Phytomonas translucens* var. *secalis* Burkholder, in Manual, 5th ed., 1939, 160;Hagborg, Canadian Jour.

Res., *20*, 1942, 317.) From M.L. *Secale*, a generic name. Distinctive characters: Cultural characters same as other forms of *Xanthomonas translucens*. This form pathogenic on rye *Secale cereale*, but not on *Triticum spp.*, *Hordeum spp.* nor *Avena spp.*

Source: Isolated from leaf spot on rye, *Secale cereale*.

Habitat: Pathogenic on rye.

23d. *Xanthomonas translucens* f. sp. *hordei-avenae* Hagborg. (Canadian Jour. Res., *20*, 1942, 317.) From M. L. *Hordeum* and *Avena*, generic names.

Distinctive characters: Cultural characters same as other forms of *Xanthomonas translucens*. Pathogenic on barley, *Hordeum spp.* and oats, *Avena spp.*, but not on wheat, *Triticium spp.*, nor rye, *Secale cereale*.

Source: Isolated 6 times from barley at various places in Canada.

Habitat: Occurs naturally on barley.

23e. *Xanthomonas translucens* f. sp. *cerealis* Hagborg. (Canadian Jour. Res., *20*, 1942, 317.) From L., of cereal.

Distinctive characters: Cultural characters same as other forms of *Xanthomonas translucens*. Pathogenic on wheat, *Triticum spp.*; oats, *Avena spp.*; barley, *Hordeum spp.*; and rye, *Secale cereale*.

Source: Isolated from wheat in Canada.

Habitat: Occurs naturally on wheat.

24. **Xanthomonas vasculorum** (Cobb) Dowson. (*Bacillus vascularum* (sic) Cobb, Agr. Gaz. of New South Wales, *4*, 1893, 777; Abst. in Cent. f. Bakt., II Abt., *1*, 1895, 41; *Bacterium vascularum* Migula, Syst. d. Bakt., *2*, 1900, 512; *Pseudomonas vascularum* Erw. Smith, U. S. Dept. Agr., Div. Veg. Phys. and Path., Bul. 28, 1901, 153; *Phytomonas vascularum* Bergey et al., Manual, 1st ed., 1923, 179; Dowson, Cent. f. Bakt., II Abt., *100*, 1939, 190.) From L. *vasculum*, a small vessel; M. L. the vascular system.

NOTE: Erw. Smith (Bact. in Rel. to Plant Dis., *3*, 1914, 88) states that probably Spegazzini (El Polville de la Cana de Azucar, June, 1895, La Plata, Supl. Rev. Azuc., Buenos Aires, No. 16, 1895) reported the disease caused by *Xanthomonas vasculorum* but that *Bacillus sacchari* Spegazzini which he claimed to be the pathogen, was a saprophyte.

Description from Smith (*loc. cit.*, 54).

Rods: 0.4 by 1.0 microns. Motile with a polar flagellum. Gram-variable.

Gelatin: Liquefaction feeble. Liquefaction good (Burkholder).

Beef-extract agar colonies: Pale yellow, smooth, glistening, not noticeably viscid.

Broth: Good growth.

Milk: Alkaline.

Nitrites not produced from nitrates.

Lipolytic (Starr and Burkholder, Phytopath., *32*, 1942, 600).

Acid but not gas from glucose, fructose and glycerol.

Starch hydrolyzed (Burkholder).

Optimum temperature 30°C. Maximum 35° to 37.5°C (Elliott, *loc. cit.*).

Habitat: Pathogenic on sugar cane, *Saccharum officinarum*, causing a bacterial gummosis.

25. **Xanthomonas vesicatoria** (Doidge) Dowson. (*Bacterium vesicatorium* Doidge, Jour. Dept. Agr , S. Africa, *1*, 1920, 718; also Ann. Appl. Biol., *7*, 1921, 428; *Pseudomonas vesicatoria* Stapp, in Sorauer, Handb. d. Pflanzenkrank., *2*, 5 Aufl., 1928, 259; *Phytomonas vesicatoria* Bergey et al., Manual, 3rd ed., 1930, 253; Dowson, Cent. f. Bakt., II Abt., *100*, 1939, 190.) From L. *vesica*, a blister; M. L. *vesicatorius*, causing blisters.

Synonyms: Gardner and Kendrick (Phytopath., *13*, 1923, 307) list *Pseudomonas exitiosa* Gardner and Kendrick (Phytopath., *11*, 1921, 55; *Bacterium exitiosum* Gardner and Kendrick, Jour. Agr. Res., *21*, 1921, 141; *Phytomonas exitiosa* Bergey et al., Manual, 1st ed., 1923, 183) and an unnamed species, Higgins (Phytopath, *12*, 1922, 513).

Rods: 0.6 to 0.7 by 1.0 to 1.5 microns

Motile with a polar flagellum. Capsules. Gram-positive. Gram-negative (Gardner and Kendrick; and Higgins).

Gelatin: Liquefaction.

Nutrient agar colonies: Good growth. Circular, wet-shining, Naples yellow, edges entire.

Milk: Casein precipitated and slowly digested. Tyrosine crystals.

Nitrites not produced from nitrates.

Indole not formed.

Hydrogen sulfide produced (Burkholder).

Lipolytic (Starr and Burkholder, Phytopath., *32*, 1942, 600).

Acid but not gas from glucose, fructose, sucrose, lactose, galactose, glycerol and dextrin.

Certain strains hydrolyze starch, others do not (Burkholder and Li, Phytopath., *31*, 1941, 753).

Optimum temperature 30°C.

Source: Isolated from spotted tomato fruits in South Africa.

Habitat: Pathogen on tomatoes, *Lycopersicon esculentum* and peppers, *Capsicum annuum*.

25a. *Xanthomonas vesicatoria* var. *raphani* (White) Starr and Burkholder. (*Bacterium vesicatoria* var. *raphani* White, Phytopath., *20*, 1930, 653; *Phytomonas vesicatoria* var. *raphani* Burkholder, in Manual, 5th ed., 1939, 154; Starr and Burkholder, Phytopath., *32*, 1942, 600.) From M. L. *Raphanus*, the radish, a generic name.

Distinctive characters: Cultural characters similar to *Xanthomonas vesicatoria*, but differs in that it is able to attack radishes, turnips, and other crucifers. Differs from *Xanthomonas campestris* in that it does not cause a vascular disease, and differs from *Xanthomonas campestris* var. *armoraciae* in that it is not pathogenic on horseradish.

Source: Isolated from leaf spots of radish and turnips in Indiana.

Habitat: Pathogenic on radish, turnips, and other crucifers; and on tomato and pepper.

26. **Xanthomonas nakatae** (Okabe) Dowson. (*Bacterium nakatae* Type B, Okabe, Jour. Soc. Trop. Agr., Formosa, *5*, 1933, 161; *Phytomonas nakatae* Burkholder, in Manual, 5th ed., 1939, 154; Dowson, Trans. Brit. Mycol. Soc., *26*, 1943, 12.) Named for Nakata, the Japanese plant pathologist.

Rods: 0.3 to 0.4 by 1.1 to 2.5 microns. Capsules. Motile with a polar flagellum. Gram-negative.

Gelatin: Liquefaction. Brown color.

Beef-extract agar colonies: Amber yellow, round, smooth, glistening, margins entire. Brown.

Broth: Moderate turbidity with yellow ring. Medium turns brown.

Milk: Casein is precipitated and digested. Tyrosine crystals. Brown color.

Nitrites not produced from nitrates.

Indole not formed.

Slight amount H_2S produced.

Acid but not gas from glucose, sucrose, maltose and lactose.

Starch: Strong diastatic action.

Optimum temperature 30° to 32°C. Maximum 39°C. Minimum 10°C.

No growth in beef extract broth plus 2 per cent salt.

Aerobic.

Distinctive character: Differs from Type A in that it produces a brown pigment in culture. (Description of Type A not seen.)

Source: Isolated from water-soaked to brown leaf spots on jute.

Habitat: Pathogenic on jute, *Corchorus capsularis*.

27. **Xanthomonas papavericola** (Bryan and McWhorter) Dowson. (*Bacterium papavericola* Bryan and McWhorter, Jour. Agr. Res., *40*, 1930, 9; *Phytomonas papavericola* Bergey et al., Manual, 4th ed., 1934, 266; Dowson, Cent. f. Bakt., II Abt., *100*, 1939, 190.) From L. *papaver*, poppy; *-cola*, dweller; M. L. *Papaver*, a generic name.

Rods: 0.6 to 0.7 by 1 to 1.7 microns. Chains. Capsules. Motile with a single polar flagellum. Gram-negative.

Gelatin: Liquefaction.

Beef agar colonies: Mustard yellow to primuline yellow, circular, margins entire.

Broth: Turbidity prompt with a yellow ring and an incomplete pellicle.

Milk: Soft coagulation, peptonization and production of tyrosine crystals.

Nitrates: A weak reaction for nitrites after 10 days.

Indole not formed.

Hydrogen sulfide is produced.

Lipolytic (Starr and Burkholder, Phytopath., *32*, 1942, 600).

Acid but not gas from glucose, galactose, fructose, sucrose, lactose, maltose, glycerol and mannitol.

Starch is hydrolyzed.

Optimum temperature 25° to 30°C. Maximum 35°C.

No growth in broth plus 5 per cent salt.

Aerobic.

Source: Isolated from black spots on leaves, buds and pods of poppy.

Habitat: Pathogenic on poppy, *Papaver rhoeas*.

28. **Xanthomonas alfalfae** (Riker et al.) Dowson. (*Bacterium alfalfae* Riker, Jones and Davis, Jour. Agr. Res., *51*, 1935, 177; *Phytomonas alfalfae* Riker et al., *ibid.*; *Pseudomonas alfalfae* Riker et al., *ibid.*; Dowson, Trans. Brit. Mycol. Soc., *26*, 1943, 11.) From Spanish, of alfalfa.

Rods: 0.45 by 2.4 microns. Motile with a polar flagellum. Gram-negative.

Gelatin: Liquefied.

Nutrient agar stroke: Growth abundant, filiform, smooth, glistening, butyrous, pale yellow.

Broth: Turbid in 24 hours. Light sediment.

Milk: Casein is precipitated and digested.

Ammonia formed slowly in a nitrate medium.

Carbohydrates: No acid in yeast broth plus sugars.

Starch is hydrolyzed.

Aerobic.

Optimum temperature 24° to 32°C. Maximum below 36°C. Minimum below 4°C.

Source: Six single cell cultures isolated from diseased alfalfa.

Habitat: Pathogenic on the leaves of alfalfa, *Medicago sativa*.

29. **Xanthomonas acernea** (Ogawa) *comb. nov.* (*Pseudomonas acernea* Ogawa, Ann. Phyt. Soc. Japan, *7*, 1937, 123; *Phytomonas acernea* Ark, Phytopath., *29*, 1939, 968.) From L. *acerneus*, of the maple.

Rods: 0.2 to 0.6 by 0.5 to 1.2 microns. Motile with one polar flagellum. Gram-negative.

Gelatin: Liquified.

Agar colonies: Round, smooth, convex, white to citron yellow, glistening, translucent with amorphous structure.

Broth: Turbid.

Milk: Slowly cleared, slightly acid. No coagulation.

Nitrites produced from nitrates.

Hydrogen sulfide produced.

No gas produced in peptone water plus sugars.

Starch not hydrolyzed.

Optimum temperature about 32°C. Thermal death point 59°C.

Aerobic.

Source: From diseased leaves of *Acer trifidum* in Japan.

Habitat: Causes a disease in *Acer spp.* and in *Aesculus turbinata* and *Koelreuteria paniculata*.

30. **Xanthomonas carotae** (Kendrick) Dowson. (*Phytomonas carotae* Kendrick, Jour. Agr. Res., *49*, 1934, 504; *Pseudomonas carotae* Kendrick, *ibid.*; Dowson, Cent. f. Bakt., II Abt., *100*, 1939, 190.) From L. *carota*, the carrot.

Rods: 0.42 to 0.85 by 1.38 to 2.75 microns. Motile with 1 or 2 polar flagella. Gram-negative.

Gelatin: Liquefied.

Potato glucose agar: Colonies round, smooth, glistening, margins entire, straw yellow in color.

Milk: Casein precipitated and milk cleared; alkaline.

Nitrites not produced from nitrates.

Indole not formed.

Acid, no gas, from glucose, *d*-galactose, xylose, *d*-mannose, *l*-arabinose, sucrose, lactose, raffinose, trehalose, *d*-mannitol and glycerol. No acid from maltose and rhamnose.

Starch not hydrolyzed.

Optimum temperature 25° to 30°C.

Tolerates 4 per cent salt at pH 7.

Aerobic.

Source: Two original isolations from diseased carrots and a reisolation from inoculated carrots were used for the description.

Habitat: Pathogenic on leaves of *Daucus carota* var. *sativa.*

31. **Xanthomonas hederae** (Arnaud) Dowson. (*Bacterium hederae* Arnaud, Compt. rend. Acad. Sci., Paris, *171*, 1920, 121; *Phytomonas hederae* Burkholder and Guterman, Phytopath., *22*, 1932, 783; Dowson, Cent. f. Bakt., II Abt., *100*, 1939, 190.) From L. *hedera*, ivy; M. L. *Hedera*, a generic name.

Description taken from Burkholder and Guterman (*loc. cit.*).

Rods: 0.6 by 2.13 microns. Motile with a single polar flagellum. Gram-negative.

Gelatin: Liquefied.

Beef-extract-agar slants: Growth good, filiform, amber yellow, butyrous.

Broth: Turbid.

Milk: Casein is precipitated and digested. Milk becomes alkaline.

Nitrites not produced from nitrates.

Hydrogen sulfide is formed.

Indole not formed.

Not lipolytic (Starr and Burkholder, Phytopath., *32*, 1942, 600).

Acid from glucose, fructose, galactose, xylose, sucrose, lactose and glycerol. Alkali from salts of acetic, citric, lactic, malic and succinic acids. The following are not utilized: arabinose, rhamnose, maltose, salicin, starch, cellulose and formic acid.

Aerobic, facultative.

Source: Isolated from diseased ivy leaves.

Habitat: Pathogenic on ivy, *Hedera helix.*

32. **Xanthomonas phormicola** (Takimoto) Dowson. (*Bacterium phormicola* Takimoto, Jour. Plant Protect., *20*, 1933, 777; *Phytomonas phormicola* Burkholder, in Manual, 5th ed., 1939, 159; Dowson, Trans. Brit. Mycol. Soc., *26*, 1943, 12.) From M. L. *Phormium*, a generic name.

Description translated by Dr. K. Togashi.

Rods: 0.5 to 0.6 by 1 to 2 microns. Motile, with a single flagellum. Gram-negative.

Gelatin: Liquefied.

Agar colonies: Light yellow, then waxy yellow; butyrous, then viscid.

Broth: Turbid, pellicle formed.

Milk: Casein coagulated slowly and precipitated, then digested. Alkaline.

Nitrites not produced from nitrates.

Indole not formed.

Hydrogen sulfide produced.

No gas from sucrose, glucose, lactose and glycerol.

No acid from various sugars in broth.

Optimum temperature about 29°C. Maximum 39°C. Minimum about 0°C.

Aerobic.

Source: Species isolated from New Zealand flax, *Phormium tenax.*

Habitat: Causes a leaf stripe of *Phormium tenax.*

33. **Xanthomonas geranii** (Burkholder) Dowson. (*Phytomonas geranii* Burkholder, Phytopath., *27*, 1937, 560; Dowson, Cent. f. Bakt., II Abt., *100*, 1939, 190.) From Greek, *geranos*, crane; M. L. *Geranium*, a generic name.

Rods: 0.75 to 2.0 microns. Motile with a single polar flagellum. Gram-negative.

Gelatin: Liquefied.

Beef-extract agar slants: Moderate to good filiform growth, glistening, primuline yellow. Develops in 24 hours.

Broth: Turbid in 24 hours. No pellicle but a moderate sediment.

Milk: Becomes clear with a heavy casein precipitate. Peptonization with crystal formation.

Nitrates reduced to ammonia.

Indole not formed.

Hydrogen sulfide formed.

Lipolytic (Starr and Burkholder, Phytopath., *32*, 1942, 600).

Acid from glucose, galactose, fructose, xylose, rhamnose, lactose, sucrose, raffinose and glycerol. Alkaline reaction from salts of citric, malic, malonic and succinic acid. No growth in arabinose or formic, hippuric, maleic or tartaric acid.

Starch not hydrolyzed.

Aerobe.

Distinctive characters: Pathogenic on *Geranium spp.*, not on the house geranium, *Pelargonium hortorum*. In culture similar to *Xanthomonas pelargonii*.

Source: Three cultures isolated from *Geranium sanguineum*.

Habitat: Pathogenic on *Geranium sanguineum*, *G. maculatum*, *G. pratense* and *G. sylvaticum*.

34. **Xanthomonas antirrhini** (Takimoto) Dowson. (*Pseudomonas antirrhini* Takimoto, Bot. Mag. Tokyo, *34*, 1920, 257; *Bacterium antirrhini* Elliott, Man. Bact. Plant Path., 1930, 93; *Phytomonas antirrhini* Magrou, in Hauduroy et al., Dict. d. bact. path., Paris, 1937, 331; Dowson, Trans. Brit. Mycol. Soc., *26*, 1943, 11.) From Gr. *antirrhinum*, snapdragon; M. L. *Antirrhinum*, a generic name.

Description from Elliott (*loc. cit.*).

Rods: 0.3 to 0.4 by 0.8 to 1.2 microns. Motile with polar flagella. Capsules. Gram-negative.

Gelatin: Liquefied.

Agar colonies: Round, glistening, white, later yellow.

Milk: Coagulated and casein digested.

Nitrites are produced from nitrates.

No gas produced.

Aerobic.

Optimum temperature 26° to 27°C. Maximum 34°C.

Habitat: Causes a leaf spot of *Antirrhinum majus*.

35. **Xanthomonas heterocea** (Vzoroff) *comb. nov.* (*Phytomonas heterocea* Vzoroff, Bull. North Caucasian Plant Prot. Sta. Roztoff-on-Don, *6–7*, 1930, 263; *Bacterium heteroceum* Burgwitz, Phytopathogenic bacteria, Leningrad, 1935, 135.) From Gr. *heterus*, another, different.

Description taken from Rev. App. Myc., *10*, 1931, 628.

Rods: 0.4 to 0.6 by 1.0 to 2.0 microns. Motile. Gram-negative.

Gelatin: Slow liquefaction.

Agar colonies: Round, convex, smooth, semi-transparent, glistening, yellow to amber, 2 mm. in diameter. Pitted surface.

Milk: No coagulation. At first acid, later alkaline.

Nitrites produced from nitrates.

Indole not formed.

Hydrogen sulfide produced.

Acid from glucose, galactose, arabinose, xylose, sucrose, maltose, salicin, glycerol and mannitol. Does not ferment lactose, inulin, ethyl alcohol, esculin, adonitol or dulcitol.

Optimum temperature 25° to 30°C.

Source: Isolated from diseased tobacco in the North Caucasus.

Habitat: Pathogenic on *Nicotiana tabacum*.

36. **Xanthomonas gummisudans** (McCulloch) Starr and Burkholder. (*Bacterium gummisudans* McCulloch, Phytopath., *14*, 1924, 63; also Jour. Agr. Res., *27*, 1924, 229; *Pseudomonas gummisudans* Stapp, in Sorauer, Handb. d. Pflanzenkrank., *2*, 5 Aufl., 1928, 54; *Phytomonas gummisudans* Bergey et al., Manual, 2nd ed., 1925, 201; Starr and Burkholder, Phytopath., *32*, 1942, 600.) From L. *gummi*, gum; *sudans*, sweating, dripping.

Rods: 0.6 to 0.8 by 1 to 2.8 microns.

Capsules. Motile with a polar flagellum. Gram-negative.

Gelatin: Liquefied.

Beef-peptone agar colonies: Amber yellow, circular, transparent, smooth, with definite margins.

Broth: Moderately turbid with a yellow ring.

Milk: Soft curd which is digested with formation of tyrosine crystals.

Nitrites not produced from nitrates.

Indole not produced.

Hydrogen sulfide produced.

Lipolytic (Starr and Burkholder, *loc. cit.*).

Acid from glucose and sucrose.

Optimum temperature 30°C. Maximum 36°C. Minimum 2°C.

Aerobic.

Source: From gummy lesions on gladiolus leaves.

Habitat: Pathogenic on leaves of gladioli.

37. **Xanthomonas lactucae** (Yamamoto) Dowson. (*Bacterium lactucae* Yamamoto, Jour. Plant Protect., *21*, 1934, 532; *Phytomonas lactucae* Bergey et al., Manual, 5th ed., 1939, 163; Dowson, Trans. Brit. Mycol. Soc., *26*, 1943, 12.) From L. *lactuca*, lettuce; M. L. *Lactuca*, a generic name.

Description translated by Dr. K. Togashi.

Rods: 0.6 to 0.8 by 1.75 to 2.8 microns. Motile with a polar flagellum. Gram-negative.

Gelatin: Liquefaction slow.

Agar colonies: Circular, convex, margin entire, surface smooth, wet-shining, yellow.

Broth: Turbid. Ring and pellicle.

Milk: Slow peptonization.

Nitrites not produced from nitrates.

Indole not produced.

Hydrogen sulfide produced.

Acid, no gas, from glucose, sucrose, and lactose in bouillon; no acid from glycerol in bouillon.

Optimum temperature 28°C. Maximum 35°C. Minimum below 2°C.

Aerobic.

Source: Isolated from leaf spot of lettuce.

Habitat: Pathogenic on leaves of asparagus lettuce, *Lactuca sativa* var. *angustata*.

38. **Xanthomonas nigromaculans** (Takimoto) Dowson. (*Bacterium nigromaculans* Takimoto, Jour. Plant Protect., Tokyo, *14*, 1927, 522; *Phytomonas nigromaculans* Magrou, in Hauduroy et al., Dict. d. Bact. Path., Paris, 1937, 387; Dowson, Trans. Brit. Mycol. Soc., *26*, 1943, 12.) From L. *niger*, black; *maculans*, spotting.

Description translated by Dr. K. Togashi.

Rods: 0.6 to 0.9 by 1.5 to 2.8 microns. Motile with 1 or 2 polar flagella. Gram-negative.

Gelatin: Liquefaction.

Agar colonies: Yellow, circular, margins entire, smooth, glistening.

Broth: Growth moderate with yellow pellicle.

Milk: Coagulation and digestion of the casein.

Nitrites not produced from nitrates.

Indole not produced.

No acid or gas from glucose, sucrose, lactose, mannitol and glycerol in peptone water.

Optimum temperature 27° to 28°C. Maximum 33°C. Minimum 0°C.

Aerobic.

Source: Isolated from lesions on leaf and petioles of burdock.

Habitat: Pathogenic on leaves and petioles of *Arctium lappa*, the burdock.

39. **Xanthomonas oryzae** (Uyeda and Ishiyama) Dowson. (*Pseudomonas oryzae* Uyeda and Ishiyama, Proc. Third Pan-Pacific Sci. Congr., Tokyo, *2*, 1926, 2112; *Bacterium oryzae* Nakata, see Elliott, Man. Bact. Plant Path., 1930, 172; *Phytomonas oryzae* Magrou, in Hauduroy et al., Dict. d. Bact. Path., Paris, 1937, 388; Dowson, Trans. Brit.

Mycol. Soc., *26*, 1943, 12.) From Gr. *oryza*, rice; M. L. *Oryza*, a generic name.

Probable synonym: *Pseudomonas itoana* Tochinai, Ann. Phytopath. Soc. Japan, *2*, 1932, 456; *Bacterium itoanum* Burgwitz, Phytopathogenic Bacteria, Leningrad, 1935, 74; *Phytomonas itoana* Magrou, in Hauduroy et al., Dict. d. Bact. Path., Paris, 1937, 370.

Rods: 0.5 to 0.8 by 1.0 to 2.0 microns. Motile with a polar flagellum. Gram-negative.

Gelatin: No liquefaction.

Nutrient agar colonies: Round, smooth, glistening, wax yellow.

Milk: Slightly acid.

Nitrites are not produced from nitrates.

Hydrogen sulfide produced.

Acid but no gas from glucose, lactose and sucrose.

Optimum temperature 26° to 30°C.

Strict aerobe.

Source: Isolated from a leaf blight of rice.

Habitat: Pathogenic on rice, *Oryza sativa*.

40. **Xanthomonas celebensis** (Gäumann) Dowson. (*Pseudomonas celebensis* Gäumann, Ztschr. f. Pflanzenkrank., *33*, 1923, 11; Meded. Inst. voor Plantenziek., Buitenzorg, *59*, 1923, 17; *Bacterium celebense* Elliott, Man. Bact. Plant Path., 1930, 108; *Phytomonas celebensis* Magrou, in Hauduroy et al., Dict. d. Bact. Path., Paris, 1937, 343; Dowson, Trans. Brit. Mycol. Soc., *26*, 1943, 11.) From M. L. of the island Celebes.

Rods: 0.9 by 1.5 microns. Motile by a polar flagellum. Gram-negative.

Agar colonies: Grayish yellow.

Broth: Thin pellicle.

Milk: Coagulated and cleared.

Nitrites not produced from nitrates.

Sodium selenite: Brick red.

Starch is hydrolyzed.

Source: From vascular bundles of diseased bananas in Celebes.

Habitat: Causes the blood disease of banana.

41. **Xanthomonas panici** (Elliott) *comb. nov.* (*Bacterium panici* Elliott, Jour. Agr. Res., *26*, 1923, 157; *Pseudomonas panici* Stapp, in Sorauer, Handb. d. Pflanzenkrank., *2*, 5 Aufl., 1928, 27; *Phytomonas panici* Bergey et al., Manual, 3rd ed., 1930, 269.) From M. L. *Panicum*, a generic name.

Rods: 0.69 by 1.66 microns. Capsules. Motile by 1 or rarely 2 polar flagella. Gram-negative.

Gelatin: Liquefaction slow.

Beef agar colonies: Round, white, smooth, glistening, margins at first entire, later undulate.

Broth: Moderate turbidity in 24 hours. Thin pellicle. Medium brownish.

Milk: Alkaline and clears.

Nitrites are produced from nitrates.

Indole not produced.

Hydrogen sulfide produced.

No gas from carbohydrates.

Starch: Hydrolysis moderate.

Optimum temperature 33°C. Maximum 45°C. Minimum 5°C.

Optimum pH 6.15 to 6.3. pH range 5.4 to 10.0.

Aerobic.

Distinctive characters: Differs from *Pseudomonas andropogoni* in that it liquefies gelatin, produces nitrites from nitrates, and does not infect sorghum and broom corn.

Source: Isolation from water soaked lesions on leaves, sheaths and culms of millet collected in Wisconsin and in S. Dakota.

Habitat: Pathogenic on proso millet, *Panicum miliaceum*.

42. **Xanthomonas proteamaculans** (Paine and Stansfield) *comb. nov.* (*Pseudomonas proteamaculans* Paine and Stansfield, Ann. Appl. Biol., *6*, 1919, 38; *Phytomonas proteamaculans* Bergey et al., Manual, 3rd ed., 1930, 247; *Bacterium proteamaculans* Elliott, Man. Bact. Plant Path., 1930, 186.) From M. L. *Protea*, a generic name; *maculans*, spotting.

Rods: 0.6 to 0.8 by 0.8 to 1.6 microns.

Motile with 1 to 3 polar flagella. Gram-positive.

Gelatin: Liquefaction.

Agar slant: Growth wet-shining, dirty white with a faint yellow tinge.

Broth: Turbid in 24 hours. Slight ring.

Milk: Acid with soft curd after 2 days. Later a separation of whey.

Nitrites are produced from nitrates.

Acid and gas from glucose, sucrose and mannitol. No acid or gas from lactose.

Starch: Slight hydrolysis.

Source: Repeated isolation from a leaf-spot of *Protea* in England.

Habitat: Pathogenic on *Protea cynaroides*.

43. **Xanthomonas manihotis** (Arthaud-Berthet) *comb. nov.* (*Bacillus manihotus* Arthaud-Berthet by Bondar, Chacaras and Quintaes *5* (4), 1912, 15; *Bacillus manihot* Bondar (and Arthaud-Berthet), Bol. Agric., São Paulo, *16*, 1915, 513; *Bacterium manihotus* Drummond and Hipolito, Ceres, *2*, 1941, 298; *Phytomonas manihotis* Viegas, Rev. d. Agr., Pieracicaba, *15*, 1940, 475.) From M. L. *Manihotus*, a generic name.

Description from Burkholder, Phytopath., *32*, 1942, 147.

Rods: 0.35 to 0.93 by 1.4 to 2.8 microns. Gram-negative and mostly non-motile. One isolate showed a few cells with 1 polar flagellum. Amaral (Instit. Biol., São Paulo, Arq., *13*, 1942, 120) states that the species is motile with one polar flagellum.

Gelatin: Liquefaction.

Beef-extract-peptone agar: Streaks raised, ivory-color, smooth, shiny, with edges entire.

Potato-glucose agar: Growth abundant, white to hyaline, very mucoid.

Broth: Turbid with a whitish granular ring.

Litmus milk: Litmus reduced and milk clears. With return of color, litmus is purple.

Indole not formed.

Hydrogen sulfide is formed.

Nitrites produced from nitrates (Drummond and Hipolito, *loc. cit.*).

Asparagine not used as a nitrogen and carbon source. No growth in nitrate synthetic broth.

Weak growth but slight acid production in synthetic medium plus glucose, d-galactose, d-fructose, d-xylose, maltose and sucrose. No growth in rhamnose, l-arabinose, d-lactose, glycerol, mannitol and salicin. Good growth with alkaline reaction in same medium plus salts of the following acids: acetic, citric, malic, maleic and succinic. The salts of formic, hippuric, lactic and tartaric acids were not utilized.

Starch not hydrolyzed. Amaral (*loc. cit.*) finds hydrolysis.

Lipolytic action slight.

Aerobic.

Optimum temperature 30°C. Maximum 38°C. Minimum 5°C.

Source: First isolated from the cassava, *Manihotus utilissima* in Brazil.

Habitat: Produces a wilt disease on various species of *Manihotus*.

44. **Xanthomonas rubrisubalbicans** (Christopher and Edgerton) *comb. nov.* (*Phytomonas rubrisubalbicans* Christopher and Edgerton, Jour. Agr. Res., *41*, 1930, 266; *Bacterium rubrisubalbicans* Burgwitz, Phytopathogenic Bacteria, Leningrad, 1935, 105.) From L. *ruber*, red; *subalbicans*, nearly white.

Rods: Short with polar flagella. Capsules. Gram-negative.

Gelatin: No liquefaction.

Bacto-glucose agar colonies: Circular, glistening, viscid, milky gray to buff. Margins translucent, entire.

Broth: Turbid after 24 hours. Pellicle and a ropy sediment.

Indole produced.

Hydrogen sulfide produced.

No gas from carbohydrates.

Starch hydrolyzed.

Optimum temperature 30°C.

Optimum pH 6.8 to 8.0.

Source: Isolated many times from mottled stripe of sugar cane in Louisiana.

Habitat: Pathogenic on sugar cane, Johnson's grass and sorghum.

45. **Xanthomonas cannae** (Bryan) *comb. nov.* (*Bacterium cannae* Bryan, Jour. Agr. Res., *21*, 1921, 152; *Phytomonas cannae* Bergey et al., Manual, 1st ed., 1923, 188; *Pseudomonas cannae* Stapp, in Sorauer, Handb. d. Pflanzenkrank., *2*, 5 Aufl., 1928, 65.) From Gr. *canna*, a reed; M. L. *Canna*, a generic name.

Rods: 0.5 to 0.7 by 1.0 to 2.0 microns. Motile with 1 to 3 polar flagella. Capsules. Gram-negative.

Gelatin: Slow liquefaction.

Agar streaks: Filiform, white, moist, with thin margins and granular centers.

Broth: Turbid, heavy sediment.

Milk: Alkaline and clears.

Nitrites are produced from nitrates.

Indole not produced.

Hydrogen sulfide produced.

Optimum temperature 35°C. Maximum 40°C. Minimum 5°C.

Aerobic.

Source: Isolated from diseased canna leaves collected in Washington, D. C. and in Illinois.

Habitat: Causes disease in *Canna indica*.

46. **Xanthomonas zingiberi** (Uyeda) *comb. nov.* (Uyeda, Cent. f. Bakt., II Abt., *17*, 1907, 383; *Pseudomonas zingiberi* Uyeda, Rept. Imp. Agr. Exp. Sta., Japan, No. 35, 1908, 114; *Bacterium zingiberi* Nakata, see Elliott, Man. Bact. Plant Path., 1930, 266; *Phytomonas zingiberi* Magrou, in Hauduroy, et al., Dict. d. Bact. Path., Paris, 1937, 437.) From L. *zingiberis*, ginger; M. L. *Zingiber*, a generic name.

Description from Stapp, in Sorauer, Handb. d. Pflanzenkrank., *2*, 5 Aufl., 1928, 65.

Rods: 0.5 to 1.1 by 0.75 to 1.8 microns. Non-motile at first, later a polar flagellum. Gram-negative.

Gelatin: Liquefaction.

Agar colonies: White.

Milk: Coagulation and peptonization of the casein.

Nitrites are produced from nitrates.

Indole not formed.

Hydrogen sulfide is formed.

No gas from glucose.

Optimum temperature 28°C. Maximum 40°C. Minimum 5°C.

Source: Isolated from ginger plant showing a rot at the base of the sprouts.

Habitat: Pathogenic on ginger, *Zingiber officinale*.

47. **Xanthomonas conjaci** (Uyeda) *comb. nov.* (*Pseudomonas conjac* Uyeda, Bot. Mag. Tokyo, *24*, 1910, 182; *Bacterium conjac* Elliott, Man. Bact. Plant Path., 1930, 121; *Phytomonas conjac* Magrou, in Hauduroy et al., Dict. d. Bact. Path., Paris, 1937, 347.) From M. L. *conjac*, the specific name of the plant which this species attacks.

Description from Elliott (*loc. cit.*).

Rods: 0.75 to 1.0 by 1.5 microns. Motile with 1 to 4 polar flagella. Gram-positive.

Gelatin colonies: Circular to irregular, light yellow.

Broth: Pellicle formed.

Milk: Coagulation.

Conjac: Liquefied.

Nitrites produced from nitrates.

Indole produced.

Hydrogen sulfide produced.

Gas from glucose.

Favorable temperature 24°C.

Habitat: Pathogenic on *Amorphophallus konjac*.

Appendix I:* The following organisms placed in the genus *Pseudomonas* apparently belong in *Xanthomonas*. Some may even be plant pathogens although they were

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* Prepared by Prof. Robert S. Breed, New York State Experiment Station, Geneva, New York, July, 1943.

isolated from water, soil and similar sources. Pigment is usually yellow and is not water-soluble.

Key to yellow and other chromogenic species in genus **Pseudomonas.**

1. Colonies yellow.
    a. Gelatin liquefied.
        b. Nitrites produced from nitrates.
            c. Acid and gas produced from glucose.
                1. *Pseudomonas fermentans.*
            cc. Acid but no gas from glucose.
                2. *Pseudomonas trifolii.*
                3. *Pseudomonas xanthe.*
            ccc. Action on glucose not recorded.
                4. *Pseudomonas caudata.*
        bb. Nitrites not produced from nitrates.
            c. Litmus milk acid or ferment lactose.
                5. *Pseudomonas perlurida.*
                6. *Pseudomonas iridescens.*
            cc. Litmus milk not coagulated. Yellow sediment.
                7. *Pseudomonas turcosa.*
            ccc. Litmus milk slimy, alkaline.
                8. *Pseudomonas ochracea.*
    aa. No liquefaction of gelatin.
        b. Nitrites produced from nitrates.
            c. Litmus milk, slow coagulation.
                9. *Pseudomonas cerevisiae.*
            cc. Litmus milk, acid but no digestion.
                10. *Pseudomonas arguta.*
            ccc. No growth in litmus milk.
                11. *Pseudomonas subcreta.*
            cccc. Action on litmus milk, not recorded.
                12. *Pseudomonas pictorum.*
        bb. Nitrites not produced from nitrates.
            c. Butter colored pellicle on litmus milk.
                13. *Pseudomonas lacunogenes.*
            cc. No surface pellicle.
                14. *Pseudomonas segnis.*
2. Colonies on gelatin blue center surrounded by yellow zone with peripheral green zone.
    a. Gelatin liquefied.
        b. Nitrites produced from nitrates.
                15. *Pseudomonas lemonnieri.*

1. **Pseudomonas fermentans** von Wolzogen Kühr. (von Wolzogen Kühr, Cent. f. Bakt., II Abt., *85*, 1932, 228; *Flavobacterium fermentans* Bergey et al., Manual, 4th ed., 1934, 155.) From Latin, *fermento*, to ferment.

Rods: 0.4 to 0.6 by 1.7 to 3.4 microns, with rounded ends, occurring singly and in pairs. Motile, with a single or occasionally 2 or 3 polar flagella. Gram-negative.

Gelatin colonies: Circular, grayish, with rapid liquefaction.

Gelatin stab: Liquefaction crateriform.

Agar colonies: Circular, slightly convex, opaque, gray by reflected, and light-brown by transmitted light.

Agar slant: Gray, becoming yellowish.

Broth: Turbid with pellicle.

Litmus milk: Acid.

Potato: Gray to yellowish growth.

Indole is formed.

Nitrites produced from nitrates.

Acid and visible gas from glucose, lactose and sucrose.

Acetylmethylcarbinol is formed.

Ammonia is formed from peptone and asparagin.

Hydrogen sulfide is formed.

Starch is hydrolyzed.

Lipase is formed. Catalase positive.

Aerobic, facultative.

Optimum temperature 37°C.

Distinctive character: Produces gas in lactose fermentation tubes.

Source: Ten cultures from the larvae of a midge (*Chironomus plumosus*) and from filtered water.

Habitat: Unknown.

2. **Pseudomonas trifolii** Huss. (Huss, Cent. f. Bakt., II Abt., *19*, 1907, 68; *Flavobacterium trifolii* Bergey et al., Manual, 1st ed., 1923, 111.) From Latin, *tres* (*tri-*), three; *folium*, leaf; M. L. *Trifolium*, clover.

Possible synonym: *Bacillus annulatus* Wright. (Wright, Memoirs Nat. Acad. Sci., *7*, 1895, 443; *Pseudomonas annulata* Chester, Man. Determ. Bact., 1901, 315; Relationship to *Bacillus annulatus* Zimmermann uncertain. Die Bakt. unserer Trink- und Nutzwässer, Chemnitz, II Reihe, 1890, 30; *Flavobacterium annulatum* Bergey et al., Manual, 1st ed., 1923, 110.)

According to Mack (Cent. f. Bakt., II Abt., *95*, 1936, 218) the following organism is to be regarded as identical with *Pseudomonas trifolii: Bacillus mesentericus aureus* Winkler (Cent. f. Bakt., II Abt., *5*, 1899, 577) regarded by Burri (Cent. f. Bakt., II Abt., *10*, 1902, 756) and Düggeli (Cent. f. Bakt., II Abt., *12*, 1904, 602) as identical with the organism which Düggeli (*loc. cit.*) names *Bacterium herbicola aureum*. The organism studied as *Bacterium herbicola* by Hüttig (Cent. f. Bakt., II Abt., *84*, 1931, 231) is not regarded as identical with the Burri and Düggeli organism by Mack. Beijerinck (Cent. f. Bakt., II Abt., *15*, 1905, 366) states that *Bacillus herbicola* of Burri and Düggeli is identical with his *Bacillus anglomerans* (Botan. Ztg., 1888, 749). If so, this binomial has priority.

Rods: 0.5 to 0.7 by 0.75 to 2.0 microns, occurring singly, in pairs and in chains. Motile, possessing a single polar flagellum. Gram-negative.

Gelatin colonies: Convex, smooth, moist, glistening, grayish-yellow.

Gelatin stab: Napiform liquefaction.

Agar colonies: Small, circular, grayish, becoming brownish-yellow.

Agar slant: Yellowish, becoming brownish-yellow streak, lacerate margin.

Broth: Turbid, with grayish-yellow pellicle and sediment.

Litmus milk: Slowly coagulated; alkaline; with yellow ring.

Potato: Thick, yellowish, flat, smooth, glistening.

Hydrogen sulfide produced.

Indole is formed.

Acid from glucose, sucrose, xylose, arabinose, and mannitol. No acid from lactose.

Nitrites produced from nitrates.

Cultures have an agreeable odor.

Volutin formed.

Aerobic, facultative.

Optimum temperature 33° to 35°C.

Source: Isolated from clover hay.

Habitat: Evidently a common organism on the leaves of plants.

3. **Pseudomonas xanthe** Zettnow. (Zettnow, Cent. f. Bakt., I Abt., Orig., *77*, 1915, 220; *Flavobacterium zettnowii* Bergey et al., Manual, 1st ed., 1923, 112; *Flavobacterium xanthium* (sic) Bergey et al., Manual, 3rd ed., 1930, 145.) From Gr. *xanthus*, yellow.

Rods: 0.5 to 0.6 by 0.4 to 1.4 microns. Motile, possessing a single or occasionally two or more very long (20 microns) polar flagella. Gram-negative.

Gelatin colonies: Circular, yellow, granular.

Gelatin stab: Pale-yellow surface growth. Brownish yellow under surface colonies. Saccate liquefaction.

Agar slant: Dark yellow, glistening, with dark yellow sediment in water of condensation. Pigment not water-soluble.

Broth: Turbid.

Litmus milk: Slightly acid. Litmus reduced.

Potato: Grayish yellow to brownish growth.

Indole formed.

Nitrites are produced from nitrates.

Acid formed in glucose.

Starch hydrolyzed.

Blood serum not liquefied.

Aerobic, facultative.

Optimum temperature 30°C.

Source: Air contamination.

4. **Pseudomonas caudata** (Wright) Conn. (*Bacillus caudatus* Wright, Memoirs Nat. Acad. Sci., 7, 1895, 444; *Bacterium caudatus* Chester, Annual Rept. Del. Col. Agr. Exp. Sta., *9*, 1897, 107; Conn, Jour. Agr. Res., *16*, 1919, 313; *Flavobacterium caudatum* Bergey et al., Manual, 1st ed., 1923, 109.) From Latin, *cauda*, tail.

Rods: Long, granular, slender, occurring singly, in pairs and in chains. Appear like cocci in old cultures. Motile, possessing a polar flagellum (Conn). Gram-negative.

Gelatin colonies: Yellow, translucent, smooth, undulate.

Gelatin stab: Villous growth in stab. Crateriform liquefaction.

Agar slant: Yellow to orange, glistening, translucent, slightly spreading. May lose power to form pigment.

Broth: Turbid, with yellow sediment.

Litmus milk: Unchanged.

Potato: Dark yellow, raised, rough, spreading.

Indole not formed.

Nitrites and ammonia produced from nitrates.

Ammonia produced from peptone.

Starch is digested.

Aerobic, facultative.

Optimum temperature 25°C.

Habitat: Water.

5. **Pseudomonas perlurida** Kellerman et al. (Kellerman, McBeth, Scales and Smith, Cent. f. Bakt., II Abt., *39*, 1913, 516; also McBeth, Soil Sci., *1*, 1916, 472; *Cellulomonas perlurida* Bergey et al., Manual, 1st ed., 1923, 163.)

Rods: 0.4 by 1.0 micron. Motile with one to three polar flagella. Gram-negative.

Gelatin stab: Liquefaction.

Agar slant: Moderate, flat, faint yellow growth.

Broth: Turbid in 5 days.

Litmus milk: Acid. Peptonization after 16 days.

Potato: Scant yellow growth with bleaching along line of growth.

Indole not formed.

Nitrites not produced from nitrates.

Ammonia is produced.

Acid from glucose, maltose, lactose, sucrose, starch, glycerol and mannitol.

Aerobic, facultative.

Optimum temperature 20°C.

Source: Soil from Virginia, Louisiana and Missouri.

Habitat: Soil.

5a. *Pseudomonas perlurida* var. *virginiana* Kellerman et al. (*loc. cit.*). Does not grow on potato and liquefies gelatin rapidly.

Source: Soil from Virginia.

6. **Pseudomonas iridescens** Stanier. (Jour. Bact., *43*, 1941, 542.) From Latin, iridescent.

Rods: 0.2 to 0.3 by 1.5 to 7.0 microns, average length 5.0 to 6.0 microns, occurring singly. Non-motile. Gram-negative.

Sea water gelatin stab: Filiform growth. Liquefaction by some strains.

Sea water agar colonies: Concave, 2 to 3 mm in diameter, smooth, glistening, translucent, pale yellow, edge irregular. After 2 to 3 days a marked iridescence. Later colonies rough, opaque, bright yellow, sunken central portion with translucent periphery.

Sea water agar slant: Growth spreading, smooth, glistening, translucent, pale yellow, iridescent, butyrous.

Sea water broth: Turbid, light yellow, granular pellicle.

Indole not formed.

Nitrites not produced from nitrates.

Hydrogen sulfide not produced.

Catalase positive.

Urease negative.

Acid from xylose, glucose, galactose, lactose, maltose, sucrose and cellobiose. No acid from arabinose. Starch and cellulose are attacked.

Aerobic.

Optimum temperature 23°C. Minimum 5°C. Maximum 30°C.

Salt range: 0.25 to 6.0 per cent. Optimum 1.0 to 4.0 per cent.

Source: Sea water.

Habitat: Common along the coast of the North Pacific.

7. **Pseudomonas turcosa** (Zimmermann) Migula. (*Bacillus turcosa* Zimmermann, Bakt. unserer Trink- und Nutzwässer, Chemnitz, *2*, 1894, 32; Migula, Syst. d. Bakt. *2*, 1900, 937; *Flavobacterium turcosum* Bergey et al., Manual, 1st ed., 1923, 111.) From M. L. *turcois*, turquoise.

Rods: 0.5 by 1.05 to 1.82 microns, occurring singly. A short polar flagellum (Migula). Gram-negative.

Gelatin colonies: Small, translucent, yellow.

Gelatin stab: Small, yellow, convex surface growth, with slight brownish tint. Liquefaction, with grayish to greenish color in liquefied portion.

Agar slant: Abundant, glistening, greenish to sulfur yellow streak.

Broth: Slightly turbid with yellow sediment.

Litmus milk: No coagulation. Yellow sediment.

Potato: Clear chromium yellow growth over entire surface.

Indole is not formed.

Nitrites not produced from nitrates.

Acid from glucose. Slight action on sucrose.

Aerobic, facultative.

Optimum temperature 30°C.

Source: Isolated by Tataroff from a well in Dorpat (Die Dorpaten Wasserbakterien, Inaug. Diss., 1891, 52, No. 24).

Habitat: Water, sea water.

8. **Pseudomonas ochracea** (Zimmermann) Chester. (*Bacillus ochraceus* Zimmermann, Bakt. unserer Trink- und Nutzwässer, Chemnitz, *1*, 1890, 60; Chester, Determinative Bacteriology, 1901, 316; *Flavobacterium ochraceum* Bergey et al., Manual, 1st ed., 1923, 110; *Chromobacterium ochraceum* Topley and Wilson, Princ. Bact. and Immun., *1*, 1931, 405.) From Greek, *ochros*, pale yellow.

Rods: 0.7 to 0.8 by 1.2 to 4.5 microns, occurring in pairs and longer chains. Slow undulatory motion (Zimmermann). Polar flagella (Lehmann and Neumann, Bakt. Diag., 1 Aufl., *2*, 1896, 255). Gram-negative.

Gelatin colonies: Pale yellow to golden, ochre yellow, slightly raised, with slightly fringed margin, granular.

Gelatin stab: Yellowish to yellow-gray surface growth. Infundibuliform liquefaction. Pale yellow to ochre yellow sediment.

Agar colonies: Thin, flat, yellowish, smooth.

Agar slant: Thin, yellowish-gray to ochraceous growth.

Broth: Slightly turbid, with pale yellow sediment.

Litmus milk: Medium becomes slimy; alkaline.

Potato: Ochre-yellow streak.

Indole is formed.

Nitrites not produced from nitrates.
Hydrogen sulfide is formed.
Aerobic, facultative.
Optimum temperature 35°C.
Source: Chemnitz tap water.
Habitat: Water.

9. **Pseudomonas cerevisiae** Fuhrmann. (Fuhrmann, Cent. f. Bakt., II Abt., *16*, 1906, 309; *Flavobacterium cerevisiae* Bergey et al., Manual, 1st ed., 1923, 111.) From Latin, *cerevisia*, beer.

Rods: Straight and slightly curved, 0.6 by 1.5 to 2.0 microns, occurring singly and in chains. Motile, possessing tuft, four to six polar flagella. Gram-negative.

Gelatin colonies: Circular, white, slightly contoured, becoming brownish-yellow.

Gelatin stab: Slight yellowish growth in stab. No liquefaction.

Agar colonies: Thin, spreading, contoured.

Agar slant: Moist, glistening, thin, pale yellow, spreading, contoured.

Litmus milk: Slow coagulation.

Potato: Yellowish-brown, spreading growth.

Indole not formed.
Nitrites produced from nitrates.
No gas from glucose.
Aerobic, facultative.
Optimum temperature 30°C.
Source: Isolated from beer.
Habitat: Unknown.

10. **Pseudomonas arguta** McBeth. (McBeth, Soil Science, *1*, 1916, 465; *Cellulomonas arguata* (sic) Bergey et al., Manual, 1st ed., 1923, 164.) From Latin, *arguo*, to show.

Rods: 0.3 by 0.8 micron. Motile with one or two polar flagella. Gram-negative.

Gelatin stab: Moderate, yellowish growth. No liquefaction in 30 days.

Agar colonies: Circular, slightly convex, soft, grayish-white, granular, entire.

Agar slant: Scant, grayish-white growth.

Potato agar slant: Moderate, yellowish, glistening.

Broth: Turbid.

Ammonia cellulose agar: Enzymatic zone 2 to 3 mm in 30 days.

Filter paper broth: Paper is reduced to loose flocculent mass which disintegrates very readily on slight agitation. More rapid decomposition when the broth contains ammonium sulfate, potassium nitrate, peptone or casein as sources of nitrogen.

Litmus milk: Acid, not digested.
Potato: No growth.
Indole not formed.
Nitrites produced from nitrates.
Ammonia not produced.

Acid from glucose, maltose, lactose, starch. No acid from glycerol, mannitol or sucrose.

Aerobic, facultative.
Optimum temperature 20°C.
Source: Isolated twice from California soils.
Habitat: Soil.

11. **Pseudomonas subcreta** McBeth and Scales. (McBeth and Scales, Bur. Plant Industry, U. S. Dept. Agr., Bul. 266, 1913, 37; *Cellulomonas subcreta* Bergey et al., Manual, 1st ed., 1923, 164.) From Latin, *sub*, under, imperfect; *creta* chalk.

Rods: 0.3 by 1.4 microns. Motile with one to five polar flagella. Gram-negative.

Gelatin stab: Filiform growth, no liquefaction.

Cellulose agar: No surface growth. Moderate, generally faint yellow growth in medium, area of growth sunken.

Agar slant: Glistening, smooth, moist, vitreous to faint yellow.

Starch agar: Enzymatic zone 2 to 4 mm.
Broth: No growth.
Litmus milk: No growth.

Potato: Growth scanty, concave due to slight liquefaction, white to faint yellow. Bleached around growth.

Indole not formed.

Trace of nitrites produced from nitrates.

Ammonia not produced.

Acid from glucose, lactose, maltose,

sucrose and starch. No acid from glycerol or mannitol.

Aerobic, facultative.

Optimum temperature 20°C.

Habitat: Soil.

12. **Pseudomonas pictorum** Gray and Thornton. (Gray and Thornton, Cent. f. Bakt., II Abt., *73*, 1928, 89; *Achromobacter pictorum* Bergey et al., Manual, 3rd ed., 1930, 217.) From Latin, *picti*, the Picts of Eastern Scotland.

Rods: 0.5 to 0.8 by 1.5 to 5.0 microns. Motile usually with a single polar flagellum. Gram-negative.

Gelatin colonies: Circular, greenish-yellow, convex, smooth, glistening, entire.

Gelatin stab: No liquefaction.

Agar colonies: Circular, yellow, convex, smooth, glistening, entire.

Agar slant: Filiform, yellow, convex, smooth, glistening, entire.

Broth: Turbid.

Nitrites produced from nitrates.

Starch not hydrolyzed.

Acid from glucose and maltose.

Attacks phenol.

Aerobic, facultative.

Optimum temperature 25°C.

Source: One culture from soil.

Habitat: Soil.

13. **Pseudomonas lacunogenes** Goresline. (Jour. Bact., *26*, 1933, 447.) From Latin *lacuno*, dimple and *genero*, to produce.

Short rods: 0.2 to 0.3 by 1.0 to 1.2 microns, with pointed ends, occurring singly or in pairs. Motile with a single polar flagellum from 2 to 15 microns in length. Gram-negative.

Plain gelatin stab: No growth.

Nutrient gelatin stab: Growth brownish-yellow, half-way down stab, heavier at surface. No liquefaction.

Nutrient agar colonies: Small, yellow; surface of the agar pitted or dimpled. After 5 days colonies 5 to 7 mm in diameter, orange-yellow, slightly raised, surrounded by a depression.

Nutrient agar slant: Growth heavy, light orange-yellow; consistency of warm butter; edge entire, slightly raised. Shallow depression formed on each side of streak. Agar softened beneath growth.

Nutrient broth: Turbid in 48 hours. Light orange-yellow pellicle; considerable viscous sediment.

Litmus milk: Alkaline; butter-colored pellicle. Reduction in bottom of tube after 10 days. No curd. No digestion.

Potato: Growth moderate, orange-yellow, smooth. No darkening.

Indole not formed.

Nitrites not produced from nitrates.

Starch agar plates not hydrolyzed.

Utilizes arabinose, galactose, lactose, fructose, maltose, melezitose, raffinose, starch, xylose, glucose, mannose, sucrose, pectin, rhamnose, salicin and dextrin. No growth in dulcitol, erythritol, glycerol, sorbitol, mannitol or inulin.

Limits of pH: 5.4 to 10.0.

Temperature relations: Optimum 28°C. Good growth at 25°C. Moderate growth at 20° and at 37°C. No growth at 10° and at 42°C.

Facultative anaerobe.

Distinctive characters: Softens agar; considerable change in viscosity of agar due to this digestion; utilization of ammonium sulfate as nitrogen source.

Source: Three cultures isolated from an experimental trickling filter receiving creamery wastes.

Habitat: Probably widely distributed in nature.

14. **Pseudomonas segnis** Goresline. (Jour. Bact., *26*, 1933, 452.) From Latin *segne*, non-energetic.

Short rods: 0.2 to 0.3 by 1.0 to 1.2 microns, with pointed ends, occurring singly or in pairs. Motile with a single polar flagellum. Gram-negative.

Plain gelatin stab: No growth.

Nutrient gelatin stab: Growth yellow, half-way down stab, best at surface. No liquefaction.

Nutrient agar colonies: Very small, light yellow; surface pitted. After 5 days colonies 5 mm in diameter.

Nutrient agar slant: Growth heavy, orange-yellow, consistency of warm butter; edge entire, slightly raised; slight depression formed on each side of growth. Agar softened beneath growth.

Nutrient broth: Turbid in 48 hours. No pellicle or surface growth. Moderate amount of sediment. Old cultures with a yellow ring at surface and occasionally a loose membrane.

Litmus milk: Slightly alkaline after 10 days. No reduction. No surface growth.

Potato: Scant yellow-orange growth. No darkening.

Indole not formed.

Nitrites not produced from nitrates.

No H_2S produced.

Starch not hydrolyzed.

Utilizes arabinose, glucose, galactose, lactose, fructose, maltose, mannose, xylose, sucrose, melezitose and raffinose.

Limits of pH: 5.8 to 9.0.

Temperature relations: Optimum 28°C. Good growth at 25°C. Moderate growth at 20° and at 37°C. No growth at 10° and at 42°C.

Facultative anaerobe.

Distinctive characters: Softens agar; considerable change in viscosity of agar due to this digestion.

Source: Isolated from an experimental trickling filter receiving creamery wastes.

Habitat: Probably widely distributed in nature.

15. **Pseudomonas lemonnieri** (Lasseur) *comb. nov.* (*Bacillus lemonnieri* Lasseur, Compt. rend. Soc. Biol. Paris, *74*, 1913, 47; Bul. de la Soc. des Sci. de Nancy, 1924; *Flavobacterium lasseuri* Bergey et al., Manual, 3rd ed., 1930, 144.) Named for Prof. G. le Monnier, a French scientist.

Rods: 0.5 to 0.7 by 1.0 to 2.0 microns, occurring singly and in pairs. Motile with a single polar flagellum. Gram-negative.

Gelatin colonies (glucose): Circular with blue center, a granular, yellow zone and a peripheral blue zone. Rapid liquefaction with blue crystals.

Gelatin stab: Liquefied.

Agar colonies: Circular, yellowish, lobate margin.

Agar slant: Yellowish streak, smooth, glistening.

Broth: Turbid with thin pellicle.

Litmus milk: After 48 hours the surface of the milk becomes yellow to cream color turning blue. A soft coagulum is formed.

Potato: Raised growth, Prussian blue in color, with variations.

Indole is not formed.

Nitrites produced from nitrates.

Aerobic, facultative.

Optimum temperature 22° to 25°C.

Habitat: Water.

Appendix II:* The following inadequately described species may belong to the genus *Xanthomonas*.

Bacterium citri deliciosae Passalacqua. (Rev. Pat. Veg., *24*, 1934, 27.) Isolated from *Citrus sp.*

Bacterium malvacearum var. *barbadense* Evelyn. (Ann. Rept. Agric. Barbados for 1926–27, 1928, 15.) Isolated from cotton.

Pseudomonas amaranti (sic) Smith. (U. S. Dept. Agr., Div. Veg. Phys. and Path. Bull., *28*, 1901, 153; *Bacterium amaranthi* Smith, Bact. in Relation to Plant Dis., *3*, 1914, 148; *Phytomonas amaranthi* Bergey et al., Manual, 1st ed., 1923, 186.) Isolated from diseased amaranthus. Growth in culture similar to *Xanthomonas campestris* and *Xanthomonas hyacinthi*.

Pseudomonas alutacea Migula. (Ledergelber *Bacillus*, Tataroff, Die Dorpater Wasserbakterien, Inaug. Diss., Dorpat,

* Prepared by Prof. Robert S. Breed, New York State Experiment Station, Geneva, New York, July, 1943.

1891, 61; Migula, Syst. d. Bakt., *2*, 1900, 936.) Isolated from water.

Pseudomonas graveolans Migula. (*Bacillus aquatilis graveolens* Tataroff, Die Dorpater Wasserbakterien, Inaug. Diss., Dorpat, 1891, 48; Migula, Syst. d. Bakt., *2*, 1900, 934.) Isolated from water. Not *Pseudomonas graveolens* Levine and Anderson (Jour. Bact., *23*, 1932, 343) isolated from musty eggs, and by Olsen and Hammer (Iowa State Coll. Jour. Sci., *9*, 1934, 125) from milk.

Pseudomonas resinacea Migula. (Harzfarbener *Bacillus*, Tataroff, Die Dorpater Wasserbakterien, Inaug. Diss., Dorpat, 1891, 64; Migula, Syst. d. Bakt., *2*, 1900, 935.) Isolated from water.

Xanthomonas taraxaci Niederhauser. (Phytopath., *33*, 1943, 961.) Pathogenic on Russian dandelion (*Taraxacum kok-saghz*).

Genus III. Methanomonas *Orla-Jensen.**

(Cent. f. Bakt., II Abt., *22*, 1909, 311.)

Cells monotrichous, capable of obtaining energy from oxidation of methane to CO_2 and water.

The type species is *Methanomonas methanica* (Söhngen) Orla-Jensen.

1. **Methanomonas methanica** (Söhngen) Orla-Jensen. (*Bacillus methanicus* Söhngen, Cent. f. Bakt., II Abt., *15*, 1906, 513; Orla-Jensen, Cent. f. Bakt., II Abt., *22*, 1909, 311.) From methane.

Short rods: 0.5 to 0.8 by 2.0 to 3.0 microns, motile in young cultures by means of a single flagellum. In older cultures nearly spherical. Can be cultivated in an atmosphere composed of one part CH_4 and two parts air on washed agar containing the necessary inorganic salts. The growth is membranous.

At the end of two weeks, the organisms changed an atmosphere containing 225 ml. CH_4 and 321 ml. O_2 to the following:

CH_4	0 ml.
CO_2	78 ml.
O_2	172 ml.

In addition, 21 ml. CO_2 was dissolved in the liquid.

Habitat: Presumably widely distributed in soil.

Genus IV. Acetobacter *Beijerinck.*†

(Proc. Kon. Akad. v. Wetenschapp., Amsterdam, *2*, 1900, 495.)

Acetobacter aceti first appeared (Kral's Sammlung v. Mikroorg., Prague, 1898, 4) as a synonym of *Bacterium aceti* Hansen. Beijerinck (*loc. cit.*) mentions *Acetobacter aceti* in a footnote of a later paper. The genus name *Acetobacter* was accepted by Fuhrmann (Beiheft Bot. Centralbl., Orig., *19*, 1905, 8) and others. From Latin, *acetum*, vinegar; *bactrum*, rod.

Synonyms: ?*Ulvina* Kützing, Algae aquae dulcis, etc., 11th decade, 1837; *Mycoderma* Thompson, Ann. d. Chem. u. Pharmacie, *83*, 1852, 89; ?*Umbina* Naegeli, Bericht über die Verhandlungen der bot. Section der 33 Versammlung deutscher Naturforscher. und Arzter. Bot. Ztg., 1857, 760; *Bacterium* Lanzi, N. Giorn. bot. ital., 1876, 257; *Torula* Saccardo, Atti Soc. Ven. Trent., *5*, 1878, 315; *Bacteriopsis* (in part) Trevisan, Atti Accad. Fisio-Medico-Statistica Milano, Ser. 4, *3*, 1885, 103; *Micrococcus* Maggi, Jour. Microg., 10, 1886; *Bacillus* Schroeter, Kryptogamen Flora von Schlesien, *3*, 1, 1886, 161; *Termobacterium* Zeidler, Cent. f. Bakt., II Abt., *2*, 1896, 739; *Acetobac-*

* Prepared by Prof. D. H. Bergey, Philadelphia, Pennsylvania, December, 1922.

† Revised by Dr. C. D. Kelly, McGill Univ., Montreal, P. Q., Canada, July, 1938; further revision by Dr. Reese H. Vaughn, Univ. of California, Berkeley, California June, 1943.

terium Ludwig, in abstract of Hoyer's Inaug. Diss., Cent. f. Bakt., II Abt., *4*, 1898, 867; *Acetimonas* Orla-Jensen, Cent. f. Bakt., II Abt., *22*, 1909, 312.

In addition, the sub-generic names *Euacetobacter* and *Acetogluconobacter* have been proposed by Asai, Jour. Agr. Soc. Japan, *11*, 1935, 502. The genus *Gluconobacter* and the sub-genera *Eugluconobacter* and *Gluconoacetobacter* Asai (*loc. cit.*) may be synonyms in whole or in part.

Individual cells ellipsoidal to long and rod-shaped, occurring singly, in pairs, or in short or long chains. Motile with polar flagella, or non-motile. Involution forms may be spherical, elongated, filamentous, club-shaped, swollen, curved or even branched. Young cells Gram-negative; old cells often Gram-variable. Obligate aerobes; as a rule strongly catalase positive, sometimes weakly so. Oxidize various organic compounds to organic acids and other oxidation products which may undergo further oxidation. Common oxidation products include acetic acid from ethyl alcohol, gluconic and sometimes ketogluconic acid from glucose, dihydroxyacetone from glycerol, sorbose from sorbitol, etc. Nutritional requirements vary from simple to complex. Development generally best in yeast infusion or yeast autolysate media with added ethyl alcohol or other oxidizable substrate. Optimum temperature variable with the species. Widely distributed in nature where they are particularly abundant in plant materials undergoing alcoholic fermentation; of importance to man for their role in the completion of the carbon cycle and for the production of vinegar.

The type species is *Acetobacter aceti* (Kützing) Beijerinck.

Key to species of genus **Acetobacter.**

I. Oxidize acetic acid to carbon dioxide and water.
  A. Capable of utilizing ammonium salts as a sole source of nitrogen (Hoyer's solution).*
    1. *Acetobacter aceti.*
  B. Do not utilize ammonium salts as a sole source of nitrogen.*
    1. Forms a thick, zoogloeal, cellulose membrane on the surface of liquid media.
      2. *Acetobacter xylinum.*
    2. Do not form a thick, zoogloeal membrane on the surface of liquid media.
      3. *Acetobacter rancens.*
      3a. *Acetobacter pasteurianum.*
      3b. *Acetobacter kuetzingianum.*

II. Do not oxidize acetic acid.
  A. Form pigments in glucose media.
    1. Dark brown to blackish pigment.
      4. *Acetobacter melanogenum.*
    2. Pink to rose pigment.
      5. *Acetobacter roseum.*
  B. Do not form pigments.
    1. Optimum temperature 30° to 35°C.
      6. *Acetobacter suboxydans.*
    2. Optimum temperature 20° to 25°C.
      7. *Acetobacter oxydans.*

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* It is not known with certainty whether *Acetobacter pasteurianum* and *Acetobacter kuetzingianum* are capable of using inorganic nitrogen as a sole source of nitrogen for growth. However, since these two species are among those first described it is advisable to retain them for the present. See *Acetobacter rancens* Beijerinck.

1. **Acetobacter aceti** (Kützing) Beijerinck. (*Ulvina aceti* Kützing, Algae aquae dulcis etc., 11th decade, 1837; *Mycoderma aceti* Thompson, Ann. d. Chem. u. Pharmacie, *83*, 1852, 89; *Umbina aceti* Naegeli, Bericht über die Verhandlingen der bot. Section der 33 Versammlung deutscher Naturforscher und Arzter. Bot. Ztg., 1857, 760; *Bacterium aceti* Lanzi, N. Giorn. bot. ital., 1876, 257; *Torula aceti* Saccardo, Atti Soc. Ven. Trent., *5*, 1878, 315; *Bacteriopsis aceti* Trevisan, Atti della Accademia Fisio-Medico-Statistica in Milano, Ser. 4, *3*, 1885, 103; *Micrococcus aceti* Maggi, Jour. Microg., *10*, 1886; *Bacillus aceti* Schroeter, Kryptogamen Flora von Schlesien, *3*, 1, 1886, 161; *Bacillus aceticus* Flügge, Die Mikroorganismen, 1886, 313; Beijerinck, Kral's Sammlung v. Mikroorg., Prague, 1898, 7; Beijerinck, Proc. Kon. Akad. v. Wetensch., Amsterdam, *2*, 1900, 495; *Bacterium hansenianum* Chester, Man. Determ. Bact., 1901, 126.) From Latin *acetum*, vinegar.

Rods: 0.4 to 0.8 by 1.0 to 2.0 microns, occurring singly and in long chains, frequently showing large club-shaped forms. Stain yellow with iodine solution. Motility variable. Motile cells possess a single polar flagellum (Vaughn, Jour. Bact., *46*, 1943, 394). Forms large, shiny colonies on beer gelatin containing 10 per cent sucrose.

Forms slimy pellicle on fluid media, or ring or turbidity without pellicle.

Acid from glucose, ethyl alcohol, propyl alcohol and glycol. No acid from arabinose, fructose, galactose, sorbose, sucrose, maltose, lactose, raffinose, dextrin, starch, glycogen, inulin, methyl alcohol, isopropyl alcohol, butyl alcohol, isobutyl alcohol, amyl alcohol, glycerol, erythritol, mannitol, dulcitol and acetaldehyde (Henneberg, Die deutsch. Essigind., *2*, 1898, 147).

Aerobic.

Distinctive characters: Marked oxidative power causing rapid and complete oxidation of substrate as glucose or ethyl alcohol; ability to utilize inorganic nitrogen salts as a sole source of nitrogen (Hoyer, Inaug. Diss., Leiden, 1898, 43; Beijerinck, Cent. f. Bakt., II Abt., *4*, 1898, 215); growth and oxidative activity in association with fermenting yeasts (Vaughn, Jour. Bact., *36*, 1938, 360).

Optimum temperature 30°C. Growth occurs between 10° and 42°C.

Habitat: Vinegar; souring fruits, vegetables and beverages.

2. **Acetobacter xylinum** (Brown) Holland. (*Bacterium xylinum* Brown, Jour. Chem. Soc., London, *49*, 1886, 439; Holland, Jour. Bact., *5*, 1920, 216; *Bacillus xylinus* Holland, *ibid.*, 221.) From Gr. *xylinus*, wooden (in reference to the cellulose in the membrane).

Rods, about 2 microns long, occurring singly and in chains. The cells have a slimy envelope which gives the cellulose reaction.

A film forms on the surface of liquids. This film becomes cartilagenous and falls to the bottom. This zoogloeal film forms on all liquid media in which growth occurs; the nature of the medium influences the thickness of the film which may vary from 1 to 250 millimeters.

X-ray pattern studies made by Khouvine, Champetier and Sutra (Compt. rend. Acad. Sci. Paris, *194*, 1932, 208) and by Barsha and Hibbert (Can. Jour. Research, *10*, 1934, 170) have shown that the cellulose contained in the membranes formed by *Acetobacter xylinum* is identical with cotton cellulose.

Acid from glucose, ethyl alcohol, propyl alcohol and glycol. No acid from arabinose, fructose, galactose, maltose, lactose, raffinose, dextrin, starch, methyl alcohol, isopropyl alcohol, butyl alcohol, isobutyl alcohol, amyl alcohol, mannitol and acetaldehyde (Henneberg, Die deutsch. Essigind., *2*, 1898, 147).

Aerobic.

Distinctive character: The production of thick, leathery, zoogloeal cellulosic membranes on the surface of liquids.

Optimum temperature 28°C.

Habitat: Vinegar; souring fruits, vegetables and beverages.

3. **Acetobacter rancens** Beijerinck. (*Bacterium rancens* Beijerinck, Cent. f. Bakt., II Abt., *4*, 1898, 211; Beijerinck, Kral's Sammlung v. Microorg., Prague, 1898, 4.) From L. *rancens*, being rancid.

Beijerinck (*loc. cit.*) in a footnote stated that "two of the many varieties of *B. rancens* have been described by Henneberg under the names of *B. oxydans* and *B. acetosum.* Hansen erroneously called this species *B. aceti* as did Brown. Neither Hansen nor Brown knew *B. aceti* Pasteur." No further morphological description is given.

The following description is taken in part from a study of a culture of *Acetobacter rancens* received from Kluyver (Vaughn).

Rods with the usual morphological appearance of cultures of acetic acid bacteria. Gram-negative. Motility variable. Motile cells possess a single polar flagellum (Vaughn, Jour. Bact., *46*, 1943, 394). Involution forms commonly appear as filaments and enlarged cells.

Wort agar slant: Growth abundant, butyrous, pale-buff in color in one week.

Yeast infusion, glucose, calcium carbonate slant: Growth abundant, butyrous and cream-colored in one week.

With petri dish cultures well isolated colonies are large, smooth and butyrous on either medium.

Broth cultures containing peptone or yeast infusion form a mucilaginous, slimy pellicle. Beijerinck (*loc. cit.*) called this polysaccharide pellicle, cellulose-like and intimated that the mucilaginous material in the pellicle was somewhat different from that produced by *Acetobacter xylinum*. The pellicle material stained blue when treated with iodine and hydroiodic acid.

Acid from glucose, ethyl alcohol, propyl alcohol, butyl alcohol, glycol, adonitol, mannitol and sorbitol. No acid from numerous other compounds tested.

Distinctive character: Production of a thin, mucilaginous, slimy, polysaccharide membrane on the surface of liquids as compared with the thick, true cellulose membrane of *Acetobacter xylinum* grown under the same conditions. Beijerinck (*loc. cit.*) reported the production of a cellulose-like membrane with some cultures of *Acetobacter rancens*.

Source: Isolated from shavings in the quick vinegar process.

Habitat: Found in fermented grain mash, malt beverages, mother of vinegar.

Beijerinck (Cent. f. Bakt., II Abt., *4*, 1898, 211) thought that the next two species were hardly more than varieties of *Acetobacter rancens*.

3a. *Acetobacter pasteurianum* (Hansen) Beijerinck. (*Mycoderma pasteurianum* Hansen, Compt. rend. d. Trav. d. Lab. d. Carlsberg, *1*, 1879, 96; *Bacterium pasteurianum* Zopf, Die Spaltpilze, 2 Aufl., 1884, 49; Beijerinck, Kral's Sammlung v. Microörg., Prague, 1898, 7.) Named for Pasteur, the French chemist and bacteriologist.

Rods: 0.4 to 0.8 by 1.0 micron, occurring singly and in chains, at times showing thick, club-shaped forms. Motility variable. Motile cells possess a single polar flagellum (Vaughn, Jour. Bact., *46*, 1943, 394). Stains blue with iodine.

Wort gelatin colonies: Small, circular, entire, gray, slimy.

Forms a dry, wrinkled folded pellicle on double beer with one per cent alcohol.

Meat infusion gelatin: Widespread, later rosette form, toothed.

Acid from glucose, ethyl alcohol, propyl alcohol and glycol. No acid from arabinose, fructose, galactose, sorbose, sucrose, maltose, lactose, raffinose, dextrin, starch, glycogen, inulin, methyl alcohol, isopropyl alcohol, butyl alcohol, isobutyl alcohol, amyl alcohol, glycerol, erythritol, mannitol, dulcitol and acetaldehyde (Henneberg, Die deutsch. Essigind., *2*, 1898, 147).

Aerobic.

Optimum temperature 30°C. Growth occurs between 5° and 42°C.

Habitat: Vinegar; beer and beer wort.

3b. *Acetobacter kuetzingianum* (Hansen) Bergey et al. (*Bacterium kuetzingianum* Hansen, Compt. rend. d. Trav. d. Lab. d. Carlsberg, *3*, 1894, 191; Bergey et al., Manual, 1st ed., 1923, 35.) Named for Kuetzing, the German botanist.

Short, thick rods, occurring singly. Rarely forming chains of notable length. Capsule stained blue with iodine and with potassium iodide. Non-motile.

Double beer gelatin colonies: Small, entire, with vermiform surface.

Wort gelatin colonies: Small, entire, with surface free of wrinkles.

Double beer: Forms a rather thick, folded pellicle. Distinguished from *Acetobacter aceti* in showing heavier growth above the surface of the media.

Acid from glucose, ethyl alcohol, propyl alcohol and glycol. No acid from arabinose, fructose, galactose, sorbose, sucrose, maltose, lactose, raffinose, dextrin, starch, glycogen, inulin, methyl alcohol, isopropyl alcohol, butyl alcohol, isobutyl alcohol, amyl alcohol, glycerol, erythritol, mannitol, dulcitol and acetaldehyde (Henneberg, Die deutsch. Essigind., *2*, 1898, 147).

Aerobic.

Optimum temperature 34°C, maximum 42°C, minimum 6 to 7°C.

Habitat: Beer. Found in double beer.

4. **Acetobacter melanogenum** Beijerinck. (Cent. f. Bakt., II Abt., *29*, 1911, 175.) From Greek *melas* (*melan*), black; *-genes*, producing.

Rods: Non-motile or motile. Motile cells possess a single polar flagellum (Vaughn, Jour. Bact., *46*, 1943, 394).

Gelatin: Apparent liquefaction probably caused by acid, not an enzyme. When held on artificial media for some time, the power of liquefying gelatin is lost, probably due to a slower production of acid. Deep brown pigment produced; gelatin becomes insoluble in boiling water and in trypsin solution.

Beer- or wort-gelatin plates: Characteristic dark brown, wide-spreading, diffuse areas.

Tap water-agar-glucose-peptone-potassium phosphate-iron citrate-chalk medium: In 24 hours at 30°C, black, spreading, diffuse areas.

Utilizes peptone as a source of nitrogen. Produces the pigment from peptone only if maltose or glucose is present as a source of carbon. When grown in glucose-peptone broth with $CaCO_3$ at 25° to 30°C, black pigment is produced after several weeks, and the carbonate is changed to calcium gluconate.

Pigment: The pigment causing the brown coloration is an aromatic substance which is blackened by iron salts. Reduces alkaline solutions of silver and mercury, blackening them.

Oxidizes mannitol and sorbitol to fructose and sorbose. Does not attack sucrose and fructose. Much gluconic acid is produced. Acid from glucose and maltose. Acetic acid produced from alcohol.

Distinctive character: The formation of dark brown to black pigment in media containing a suitable substrate; particularly glucose.

Source: Isolated from beer.

Habitat: Causes light-colored beer to become darker brown. It is a very strong beer-vinegar bacterium. Also found in souring fruits.

5. **Acetobacter roseum** Vaughn. (*Bacterium hoshigaki* var. *rosea* Takahashi and Asai, Cent. f. Bakt., II Abt., *82*, 1930, 390; *Acetobacter hoshigaki* Bergey et al., Manual, 4th ed., 1934, 39; Vaughn, Wallerstein Lab. Communications, *5*, No. 14, 1942, 20.) From Latin, *rosa*, rose.

Rods: 0.7 to 0.9 by 1.5 to 1.8 microns, generally occurring singly, at most in pairs, often in chains. Non-motile. Pellicle on fluid media yields no starch or cellulose reaction.

Koji (a mixture of rice and mold spores used to start fermentation of Japanese bread and saké) extract agar colonies: Small, granular, circular, glistening, umbonate, becoming brownish.

Wort agar colonies: Circular, milky-white, becoming brownish in center and yellowish at periphery.

Glucose saké agar: Circular, milky-white, granular, umbonate, entire.

Hoshigaki (dried persimmons) extract agar: Circular, milky-white, granular, becoming yellowish-brown in the center and grayish-white at the periphery.

Koji extract agar streak: Grayish-white, glistening with ciliate margin, becoming purple brown to brown.

Koji extract: Turbid with thin film, ascending on wall of tube.

Bouillon: Turbid with ring formation.

Yeast infusion glucose agar: Colonies similar to those on wort agar.

Yeast infusion glucose broth: Turbid with thin, ascending film.

Red color produced on saké wort agar and all media containing calcium carbonate.

Acid from glucose, fructose, galactose, arabinose, glycerol, mannitol, ethyl and propyl alcohol. No acid from maltose, sucrose, lactose, raffinose, dextrin, starch, inulin, sorbitol, glycogen, isodulcitol and methyl alcohol.

Forms gluconic acid from glucose.

Aerobic.

Optimum temperatures 30° to 35°C; maximum 40° to 41°C; minimum 10° to 15°C.

Thermal death point 50°C for 5 minutes.

Distinctive character: The formation of a rose to red pigment in suitable media; particularly those containing glucose and calcium carbonate.

Source: Isolated from fermenting mash of dried persimmons (hoshigaki), and souring figs and dates.

NOTE: Vaughn, Wallerstein Lab. Communications, *5*, No. 14, 1942, 20, has proposed the name *Acetobacter roseum* to replace the name *Acetobacter hoshigaki*. As originally described, this organism was given the name *Bacterium hoshigaki* var. *rosea* by Takahashi and Asai (*loc. cit.*) without the authors having first named and described the species *Bacterium hoshigaki*. The Japanese word "hoshigaki" has been used in a confusing manner viz. Takahashi and Asai, *loc. cit.* (*Bacterium industrium* var. *hoshigaki*) and Takahashi and Asai, Jour. Agr. Chem. Soc. Japan, *9*, 1933, 351 and Cent. f. Bakt., II Abt., 87, 1933, 385 (*Bacterium hoshigaki* var. *glucuronicum* I, II and III). None of these Japanese names are in the form of true binomials.

6. **Acetobacter suboxydans** Kluyver and de Leeuw. (Paper read at the convention of the Dutch Society of Microbiology, Utrecht, December, 1923, see Tijdschrift v. Vergelijkende Geneeskunde, *10*, Afl. 2–3, 1924.) From L. *sub*, under, less; Gr. *oxys*, sharp, acid; *dans*, giving, i.e. less acid giving; less oxidizing.

Short rods: Occurring singly or in chains. Non-motile. Morphologically like *Acetobacter rancens*.

Forms very thin, hardly visible pellicle on fluid media.

Wort agar colonies: Very small, circular, slightly yellow.

Acid from ethyl alcohol, propyl alcohol, glycol, glucose, glycerol and sorbitol.

Optimum temperature 30°C.

Distinctive character: Partial oxidation of substrates as indicated by the formation of calcium 5-keto gluconate crystals on the surface of agar slants containing glucose and calcium carbonate.

Source: Isolated from spoiled beer.

Habitat: Beer.

7. **Acetobacter oxydans** (Henneberg) Bergey et al. (*Bacterium oxydans* Henneberg, Cent. f. Bakt., II Abt., *3*, 1897, 223; *Bacillus oxydans* Migula, Syst. d. Bakt., *2*, 1900, 800; Bergey et al., Manual, 1st ed., 1923, 36.) From Gr. *oxys*, sharp, acid; *dans*, giving.

Rods: 0.8 to 1.2 by 2.4 to 2.7 microns, occurring singly and in chains. Motile

cells possess a single polar flagellum (Vaughn, Jour. Bact., *46*, 1943, 394). The chains show bud-like swellings.

Gelatin colonies: Circular, becoming irregular in shape with peculiar ramifications.

Acid from arabinose, fructose, glucose, galactose, sucrose, maltose, raffinose, dextrin, ethyl alcohol, propyl alcohol, erythritol, mannitol, glycol and glycerol. No acid from sorbose, lactose, starch, glycogen, inulin, methyl alcohol, isopropyl alcohol, butyl alcohol, isobutyl alcohol, amyl alcohol, dulcitol and acetaldehyde (Henneberg, Die deutsch. Essigind., *2*, 1898, 147).

Aerobic.

Optimum temperature 18° to 21°C.

Distinctive characters: Low optimum temperature for growth and oxidation of substrates; and the ability to oxidize a large number of substrates.

Habitat: Beer.

Appendix: The following species have been described, but until more comparative studies have been made, no change in nomenclature is recommended or advisable.

1. **Acetobacter zeidleri** Beijerinck. (*Termobacterium aceti* Zeidler, Cent. f. Bakt., II Abt., *2*, 1896, 739; *Bacterium zeidleri* Beijerinck, *Acetobacter zeidleri* Beijerinck, Kral's Sammlung v. Mikroorg., Prague, 1898, 7; *Bacillus zeidleri* Migula, Syst. d. Bakt., *2*, 1900, 801; *Acetobacter lindneri* Bergey et al., Manual, 1st ed., 1923, 36.) Named for A. Zeidler, who first isolated this species.

Rods, occurring singly and in chains, showing large sausage-shaped involution forms. Motile with a single polar flagellum (Zeidler, Cent. f. Bakt., II Abt., *4*, 1898, 669).

Wort gelatin: Small, circular, slightly granular, yellowish-brown, entire colonies. No liquefaction.

Dirty, yellowish-brown pellicle on liquid media.

Wort gelatin slant: Strongly glistening, transparent, whitish in center, smooth, very weakly liquefied.

Potato: Very scant growth.

Acid from glucose, ethyl alcohol, propyl alcohol and glycol. No acid from arabinose, fructose, galactose, maltose, lactose, raffinose, dextrin, glycogen methyl alcohol, isopropyl alcohol, butyl alcohol, isobutyl alcohol, amyl alcohol, glycerol, mannitol and acetaldehyde (Henneberg, Die deutsch. Essigind., *2*, 1898, 147).

Aerobic, facultative.

Optimum temperature 25°C.

Habitat: Beer wort.

2. **Acetobacter acetosum** (Henneberg) Bergey et al. (*Bacterium acetosum* Henneberg, Cent. f. Bakt., II Abt., *3*, 1897, 223; Bergey et al., Manual, 1st ed., 1923, 36.) From Latin, *acetum*, vinegar.

Rods: 0.4 to 0.8 by 1.0 micron, occurring singly and in chains. Non-motile. Stains yellow with iodine.

On beer, yeast water and glucose solutions a firm, coherent, uniform, smooth, white film that becomes folded (Henneberg, Gärungsbakt., *2*, 1926, 201).

Acid from glucose, galactose, ethyl alcohol, and propyl alcohol. No acid from arabinose, fructose, sorbose, sucrose, maltose, lactose, raffinose, dextrin, starch, glycogen, inulin, methyl alcohol, isopropyl alcohol, butyl alcohol, isobutyl alcohol, amyl alcohol, glycerol, erythritol, mannitol, dulcitol and acetaldehyde (Henneberg, Die deutsch. Essigind., *2*, 1898, 147).

Optimum temperature 28°C, maximum 36°C, minimum 8°C (Henneberg, Cent. f. Bakt., II Abt., *4*, 1898, 14).

Habitat: Beer.

3. **Acetobacter ascendens** (Henneberg) Bergey et al. (*Bacterium ascendens* Henneberg, Zeitschr. f. deutsche Essigind., Berlin, No. 19 to 23, 1898, 145; also see Cent. f. Bakt., II Abt., *4*, 1898, 933; Bergey et al., Manual, 1st ed., 1923, 37.) From Latin, *ascendo*, pp. *ascendens*, ascending.

Rods, occurring singly, rarely in chains.

Non-motile. Do not give the cellulose reaction with iodine solution.

Glucose gelatin colonies: Dry, white, with white area surrounding the colony.

Fluid cultures have a tough pellicle rising on the wall of the flask.

Acid from ethyl alcohol, propyl alcohol and glycol. No acid from arabinose, fructose, glucose, galactose, sucrose, maltose, lactose, raffinose, dextrin, starch, methyl alcohol, isopropyl alcohol, butyl alcohol, isobutyl alcohol, amyl alcohol, glycerin, mannitol and acetaldehyde (Henneberg, Die deutsch. Essigind., *2*, 1898, 147).

Aerobic.

Optimum temperature 31°C.

Habitat: Isolated from vinegar and from red wine.

4. **Acetobacter plicatum** Fuhrmann. (Beihefte z. bot. Centralbl., Orig., *19*, 1905, 8.) Description given in Cent. f. Bakt., II Abt., *15*, 1906, 377. From *plicatus*, folded.

Rods: 0.55 to 0.7 by 0.75 to 0.9 microns when grown on agar at 28° to 30°C. Young streak cultures 0.4 to 0.6 by 1.4 to 1.6 microns with homogeneous staining when grown on beef-extract-gelatin at 22°C. 0.5 by 1.5 to 1.7 microns with uneven staining (polar) when grown on wine gelatin. At about 40°C the organisms form swollen and greatly elongated forms. Non-motile.

Agar slant: Pale yellowish, translucent growth.

Alcohol-free beer with glucose and sucrose: Turbid with thick pellicles.

Potato: Growth limited.

Ferments alcohol to form acetic acid.

Optimum temperature 28° to 30°C.

Habitat: Wine.

5. **Acetobacter acetigenum** (Henneberg) Bergey et al. (*Bacterium acetigenum* Henneberg, Cent. f. Bakt., II Abt., *4*, 1898, 14; *Bacillus acetigenum* Migula, Syst. d. Bakt., *2*, 1900, 801; Bergey et al., Manual, 1st ed., 1923, 35.) From Latin, producing vinegar.

Rods, occurring singly and in pairs. 0.8 to 1.2 by 1.2 to 1.4 microns. Motile. Cells give a cellulose reaction with H_2SO_4 and iodine.

Glucose gelatin colonies: Raised, grayish, slimy.

Fluid cultures show a tough, slimy pellicle.

Acid from glucose, ethyl alcohol, propyl alcohol and glycol. No acid from arabinose, fructose, galactose, sorbose, sucrose, maltose, lactose, raffinose, dextrin, starch, glycogen, inulin, methyl alcohol, isopropyl alcohol, butyl alcohol, isobutyl alcohol, amyl alcohol, glycerol, erythritol, mannitol, dulcitol and acetaldehyde (Henneberg, Die deutsch. Essigind., *2*, 1898, 147).

Aerobic.

Optimum temperature 33°C. Thermal death point 43° to 45°C for 5 minutes.

Habitat: Vinegar.

6. **Acetobacter industrium** (Henneberg) Bergey et al. (*Bacterium industrium* Henneberg, Zeitschr. f. deutsche Essigindustrie, Berlin, 1898; Cent. f. Bakt., II Abt., *4*, 1898, 933; *Bacillus industrius* Migula, Syst. d. Bakt., *2*, 1900, 801; Bergey et al., Manual, 1st ed., 1923, 36.) From Latin *industrius*, diligent.

Rods: 0.3 to 0.8 by 2.4 to 20 microns, occurring singly and in chains. No distinct color produced with iodine. Motile.

Forms pellicle on fluid culture media.

Acid from arabinose, fructose, glucose, galactose, sucrose, maltose, lactose, raffinose, starch, dextrin, ethyl alcohol, propyl alcohol, glycol, glycerol and mannitol. No acid from isopropyl alcohol, butyl alcohol, isobutyl alcohol, amyl alcohol and acetaldehyde (Henneberg, Die deutsch. Essigind., *2*, 1898, 147).

Aerobic.

Optimum temperature 23°C. Maximum 35°C. Minimum 8°C.

Habitat: Beer wort.

7. **Bacterium schuezenbachii** Henneberg. (Die deutsche Essigind., No. 11–18, 1906; also Cent. f. Bakt., II Abt., *17*, 1906, 790.) Named for Schüzenbach, the inventor of the German quick vinegar process.

Rods: 0.3 to 0.4 by 1.0 to 3.6 microns, occurring singly, in pairs and chains. The cells are round, oval or elongated, not infrequently sickle-shaped or irregularly bent with rounded or pointed ends. Not stained with iodine. Non-motile.

Wort gelatin colonies: Round, shiny, transparent with yellowish-brown centers.

A non-coherent film produced on the surface of liquid media.

Acid from arabinose, fructose, glucose, galactose, maltose, lactose, dextrin, ethyl alcohol, propyl alcohol, glycerol and erythritol. Small amount of acid from sucrose and raffinose. No acid from mannitol (Henneberg, Handbuch d. Gärungsbakt., *2*, 1925, 239).

Temperature relations: Optimum 25° to 27.5°C. Scant growth at 34° to 35°C and 13° to 15°C. No growth at 37° and 7.5°C.

Source: Isolated from vinegar in the quick vinegar process.

Habitat: Produces acetic acid in quick vinegar process.

8. **Bacterium xylinoides** Henneberg. (Die deutsche Essigind., No. 11 to 18, 1906; also Cent. f. Bakt., II Abt., *17*, 1906, 794.) From Greek, woody.

Rods: 0.5 to 0.8 microns (round cells) and 0.5 to 1.2 microns (long forms), occurring singly, in pairs or chains, cells round and as short and long rods. The thick membrane like that produced by *Acetobacter xylinum* gives the reaction for cellulose with iodine and sulfuric acid, but the thin membrane does not.

Wort gelatin: Colonies are produced like drops of water, often with light brown kernels in the center.

Wort gelatin streak: Growth transparent at first, later whitish.

Three types of membrane on fluid media are formed by this species and all three may even be found on a culture at one time. A thin, firm, coherent membrane like that of *Bacterium orleanense* may be formed or one that is voluminous, scumlike (like coagulated egg-white), coherent, somewhat slimy and finally thick like that of *Bacterium xylinum*. Also a membrane may be formed that is intermediate in type.

Acid from arabinose, glucose, galactose, sucrose, maltose, ethyl alcohol, propyl alcohol, glycerol and erythritol. Small amount of acid from fructose and mannitol.

Temperature relations: Optimum 28°C. Slight growth at 14°C. No growth at 6°C.

Source: Isolated from wine vinegar from the Rhine and other sections.

Habitat: Found in vinegar made by the Orleans method.

9. **Bacterium orleanense** Henneberg. (Die deutsche Essigind., No. 11–18, 1906; also Cent. f. Bakt., II Abt., *17*, 1906, 792.) Latinized, of Orleans.

Rods: 0.4 to 0.5 by 1.2 to 2.1 microns, occurring singly or in chains. The cells are round, elongated or as involution forms, with straight or curved cells appearing. Not stained with iodine. Non-motile.

Wort gelatin: Colonies irregular in form, whitish in color, about 1 mm. in diameter in 2 days.

Wort gelatin streak: Growth often slimy, transparent, liquid mass with yellowish-brown sediment.

Wort agar streak: Some strains form isolated, moist, slimy, transparent colonies and on the water of condensation isolated whitish colonies are formed. Other strains form a coherent, transparent coating with a light brown precipitate later and individual, distinct, round colonies of the same color.

Characteristic of this species is the firm coherent film on the surface of liquid media.

Acid from arabinose, glucose, galactose, maltose, lactose, raffinose, dextrin, ethyl alcohol, propyl alcohol, glycerol, erythritol and mannitol. Small amount of acid from fructose and sucrose (Henneberg, Handbuch d. Gärungsbakt., *2*, 1926, 239).

Temperature relations: Optimum 20° to 30°C. Slight growth at 35° to 36°C and 14° to 15°C. No growth at 39° and at 7° to 8°C.

Source: Isolated from vinegar in the quick vinegar process.

Habitat: Can be used both in the quick or German process and the Orleans method of making vinegar.

10. **Bacterium vini acetati** Henneberg. (Die deutsche Essigind., No. 11–18, 1906; also Cent. f. Bakt., II Abt., *17*, 1906, 797.) From Latin *vinum*, wine and *acetum*, vinegar.

Rods: 0.3 to 0.8 by 0.8 to 2.0 microns, occurring singly, in pairs and sometimes as short chains of three; cell round, oval or slightly elongated, and rarely moderately long forms. Streptococcus-like cells are found on older agar cultures and spindle forms in beer gelatin with 10 per cent sucrose.

Wort gelatin: Round, moist, shiny, transparent colonies with whitish sediment in the center.

The film on liquid media is not strongly coherent and the liquid is cloudy.

Acid from arabinose, fructose, glucose, galactose, sucrose, maltose, raffinose, dextrin, ethyl alcohol, propyl alcohol, glycerol and erythritol. No acid from lactose (Henneberg, Handbuch d. Gärungsbakt., *2*, 1925, 239).

Optimum temperature 28° to 33°C.

Source: Wine vinegar.

Habitat: Found in vinegar made by the Orleans method for wine vinegar.

11. **Bacterium curvum** Henneberg. (Die deutsche Essigind., No. 11–18, 1906; also Cent. f. Bakt., II Abt., *17*, 1906, 791.) From Latin, *curvus*, bent.

Rods: 0.4 to 0.5 by 2.0 to 2.4 microns, occurring singly or in pairs, cells usually oval or elongated, not infrequently sickle-shaped, with rounded or pointed ends. Not stained with iodine solution. Non-motile.

Wort gelatin: Transparent, round colonies with raised center and edge, frequently whitish and dry.

A non-coherent scanty pellicle is formed on the surface of liquid media which sinks readily and the liquid is quite turbid.

Forms round white islands on the surface of wort with 3 per cent alcohol.

In old cultures on beer are to be found numerous smooth light brown raised colonies about 1 mm in diameter on the uniform transparent base of the surface membrane.

Acid from arabinose, glucose, raffinose, dextrin, ethyl alcohol, propyl alcohol, glycerol and erythritol. Small amount of acid from fructose, galactose and mannitol. No acid from sucrose, maltose and lactose (Henneberg, Handbuch d. Gärungsbakt., *2*, 1925, 239).

Temperature relations: Optimum 25° to 30°C. Scant growth at 16° to 17°C. No growth at 7° to 8°C. Growth at 35°C. No growth at 39°C.

Source: Isolated from vinegar in the quick vinegar process.

Habitat: Produces acetic acid in the quick vinegar process.

12. **Acetobacter viscosum** Shimwell. (*Bacterium aceti viscosum* Day and Baker, Cent. f. Bakt., II Abt., *36*, 1913, 433; *Bacillus aceti viscosum* Day and Baker, *ibid.*, 437; Also see Baker, Day and Hulton, Jour. Inst. Brewing, —, 1912, 651; Shimwell, Jour. Inst. Brewing, *42* (N. S. *32*), 1936, 586.) From Latin, viscous or slimy.

Rods: 0.4 by 1.2 microns which produce ropiness in beer. No capsules observed. Non-motile as a rule. Weakly Gram-positive.

Source: From ropy beer.

13. **Acetobacter capsulatum** Shimwell. (Jour. Inst. Brewing, *42* (N. S. *32*), 1936, 585.) From Latin, capsulated.

Coccoid rods, 0.8 to 1.0 micron in malt extract media. 0.6 to 1.5 microns in other media. Produce ropiness in beer. Capsulated. Motile. Gram-negative.

Source: From ropy beer.

14. **Acetobacter gluconicum** (Hermann).* (*Bacterium gluconicum* Hermann, Biochem. Zeit., *192*, 1928, 198; also see Hermann, Biochem. Zeit., *205*, 1929, 297 and Hermann and Neuschul, Biochem. Zeit., *233*, 1931, 129.)

It is unfortunate that an organism so well described must be placed with other species of uncertain standing. However, this organism is so closely related to the other organisms described in the literature that further study is necessary.

Source: From kombucha, a mixture of fungi and bacteria from tea infusions.

15. **Acetobacter turbidans** Cosbie, Tošić and Walker. (Jour. Inst. Brewing, *48*, 1942, 82.)

This beer vinegar bacterium is characterized by the production of intense turbidity in beer and ale. The description given does not, at present, warrant recognition of the organism as a new species.

Source: From beer.

16. **Bacterium dihydroxyacetonicum** Virtanen and Bärlund. (Biochem. Zeit., *169*, 1926, 170.)

There is no adequate description of this bacterium, and it is doubtful whether it can be properly evaluated since various species of *Acetobacter* also possess the ability to produce dihydroxyacetone from glycerol. Consideration of this as a *nomen nudem* was indicated by Virtanen to Vaughn in a personal communication in 1938.

Source: From beet juice.

17. **Acetobacter peroxydans** Visser 't Hooft. (Inaug. Diss., Delft, 1925, 98.)

The exact taxonomic position of this bacterium will not be clear until further comparative studies have been made.

Source: From hydrogen peroxide solutions.

Genus V. **Protaminobacter** *den Dooren de Jong.*†

(Bijdrage tot de kennis van het mineralisatieproces. Thesis, Rotterdam, 1926, 159.) From M. L., protamine and Latin, *bactrum*, rod.

Cells motile or non-motile. Capable of dissimilating alkylamins. Pigmentation frequent. Soil or water forms.

The type species is *Protaminobacter alboflavum* den Dooren de Jong.

Key to the species of genus **Protaminobacter.**

I. Non-motile. Gelatin colonies light yellow to colorless.
   1. *Protaminobacter alboflavum.*

II. Motile. Gelatin colonies red.
   2. *Protaminobacter rubrum.*

1. **Protaminobacter alboflavum** den Dooren de Jong. (Thesis, Rotterdam, 1926, 159; also see Cent. f. Bakt., II Abt., *71*, 1927, 218.) From Latin *albus*, white; *flavus*, yellow.

Rods: Non-motile. Gram-negative.

* It is uncertain at present who first used this combination.

† Prepared by Prof. D. H. Bergey, Philadelphia, Pennsylvania, June, 1929; further revision by Prof. Robert S. Breed, New York State Experiment Station, Geneva New York, April, 1943.

Gelatin colonies: Circular, dry, light yellow or colorless.

Gelatin stab: No liquefaction.

Agar colonies: Circular, opaque, pigment bright red, yellow, light gray or colorless.

Amine agar colonies: Circular, white to dark yellow.

See table below for list of organic substances utilized.

TABLE I.—*Organic Substances Utilized as a Source of Carbon by Varieties of* ***Protaminobacter alboflavum***

ORGANIC ACIDS	α	β	γ	δ
Acetic	+	+	+	+
Valerianic	+	+	0	+
α-crotonic	+	+	+	+
Undecyclic	0	0	0	+
Lactic	+	0	0	+
β-oxybutyric	+	+	+	+
Succinic	+	+	+	+
Formic	+	+	+	+
Glutaric	0	+	0	+
Adipic	0	0	0	+
Fumaric	+	+	+	+
Malic	+	+	+	+
Tartaric	0	+	0	0
Citric	+	+	+	+
β-phenylpropionic	+	0	0	0
Quinic	+	+	0	0

AMINO COMPOUNDS	α	β	γ	δ
α-alanin	0	0	+	+
α - aminocapronic acid	+	0	+	0
Leucin	+	+	0	0
Propionamid	+	0	+	0
Capronamid	+	0	+	0
Uric acid	+	0	0	0
Hippuric acid	+	0	0	0
ALCOHOL				
Ethyl	+	+	+	+
SUGAR				
Glucose	+	+	+	0

AMINES	α	β	γ	δ
Ethyl	+	+	+	+
Diethyl	+	+	0	0
Propyl	+	+	+	+
Isopropyl	0	+	0	0
Dipropyl	+	+	0	0
Tripropyl	+	0	0	0
Butyl	+	0	+	0
Isobutyl	+	+	+	+
Diisobutyl	+	+	0	0
Amyl	+	+	+	+
Diamyl	0	+	0	0
Ethanol	+	+	+	+
Glucosamin	+	+	+	0
Benzyl	+	0	+	0

Catalase is formed.

Aerobic, facultative.

Optimum temperature 30°C.

Habitat: Soil and water.

NOTE: The author recognizes four varieties of this species which he differentiates on the basis of organic substances attacked (see Table) and pigment produced. Variety α shows light yellow growth on gelatin, bright red on agar and yellow on amine agar. Variety β is light yellow on gelatin, yellow on agar and dark yellow on amine agar. Variety γ is light yellow on gelatin, light gray on agar and yellow on amine agar. Variety δ is colorless on gelatin and agar and white on amine agar.

2. **Protaminobacter rubrum** den Dooren de Jong. (Thesis, Rotterdam, 1926, 159; also see Cent. f. Bakt., II Abt., *71*, 1927, 218.) From Latin, *ruber*, red.

Rods: Motile with single polar flagellum (Weaver, Samuels and Sherago, Jour. Bact., *35*, 1938, 59). Gram-negative.

Gelatin colonies: Circular, red, dry.

Gelatin stab: No liquefaction.

Agar colonies: Circular, red, opaque.

Amine agar colonies: Circular, dark red.

The following organic acids are attacked: Acetic, lactic, β-oxybutyric, glycerinic, succinic, malonic, formic, methyl formic, glutaric, maleinic, fumaric, malic, tartaric, citric and quinic.

The following amino compounds are attacked: Sarcosin, betain, hippuric acid, asparagine, propionamid, capronamid, lactamid, succinamid, allantoin and uric acid.

Glucose is fermented.

Catalase is formed.

Aerobic, facultative.

Optimum temperature 30°C.

Habitat: Soil and water.

Genus VI. Mycoplana *Gray and Thornton.**

(Cent. f. Bakt., II Abt., *73*, 1928, 82.) From Greek, *mykēs*, fungus; *planē*, a wanderer or traveller.

Cells branching, especially in young cultures. Frequently banded when stained. Capable of using phenol and similar aromatic compounds as a sole source of energy. Grow well on standard culture media.

Type species *Mycoplana dimorpha* Gray and Thornton.

Key to the species of genus Mycoplana.

I. Gelatin not liquefied.
   1. *Mycoplana dimorpha.*

II. Gelatin liquefied.
   2. *Mycoplana bullata.*

1. **Mycoplana dimorpha** Gray and Thornton. (Cent. f. Bakt., II Abt., *73*, 1928, 82.) From Greek, *di*, two; *morphos*, forms.

Short, curved and irregular rods, 0.5 to 0.7 by 1.25 to 4.5 microns, showing branching especially in young cultures. †Motile, with long polar flagella. Gram-negative.

Gelatin colonies: Circular, buff, smooth, resinous, entire.

Gelatin stab: No liquefaction. Growth filiform.

Agar colonies: Circular, buff, convex, smooth, glistening, entire.

Agar slant: Filiform, white, convex, glistening, entire.

Broth: Turbid, with surface ring.

Nitrites not produced from nitrates but gas evolved in fermentation tubes.

Starch hydrolyzed.

No acid from carbohydrate media.

Attacks phenol.

Aerobic.

Optimum temperature below 30°C.

Source: One strain isolated from soil.

Habitat: Probably in soil.

2. **Mycoplana bullata** Gray and Thornton. (Cent. f. Bakt., II Abt., *73*, 1928, 83.) From Latin, *bullatus*, furnished with a boss or knob.

Rods, curved and irregular, branching, 0.8 to 1.0 by 2.25 to 4.5 microns. †Motile with polar flagella. Gram-negative.

Gelatin colonies: Circular, buff, smooth, glistening, edge diffuse. Partially liquefied.

Gelatin stab: Saccate liquefaction.

Agar colonies: Circular, white, convex, smooth, glistening, entire.

Agar slant: Filiform, white, convex, smooth, glistening, entire.

Broth: Turbid.

Nitrites not produced from nitrates. Gas, presumably N, in fermentation tubes.

Starch not hydrolyzed.

No acid from carbohydrate media.

Attacks phenol.

Aerobic.

Optimum temperature below 30°C.

Source: Two strains isolated from soil.

Habitat: Probably in soil.

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* Prepared by Prof. D. H. Bergey, Philadelphia, Pennsylvania, June, 1929.

† The original statements regarding the flagellation of these species are contradictory. The first reads "Polar, peritrichous; the second "Polar or peritrichous". Drawings given usually indicate peritrichous rather than polar flagellation. Further study is needed before these species can be properly placed in relation to other known species.—Editors.

TRIBE II. SPIRILLEAE KLUYVER AND VAN NIEL.

(Cent. f. Bakt., II Abt., *94*, 1936, 346.)

More or less spirally curved cells.

Key to the genera of tribe **Spirilleae.**

I. Generally motile by means of a single polar flagellum.
  A. Short, bent rods occurring singly or united into spirals.
    Genus I. *Vibrio*, p. 192.
  B. Slightly curved rods of variable length. Strict anaerobes which reduce sulfates to hydrogen sulfide.
    Genus II. *Desulfovibrio*, p. 207.
  C. Cells oxidize cellulose forming oxycellulose. Growth on ordinary culture media is feeble.
    1. Long, slightly curved rods with rounded ends.
      Genus III. *Cellvibrio*, p. 209.
    2. Short, curved rods with pointed ends.
      Genus IV. *Cellfalcicula*, p. 211.
II. Generally motile by means of a tuft of polar flagella. Cells of varying thickness, and length and pitch of spiral, forming either long curves or portions of a turn.
  A. Oxidize inorganic sulfur compounds. Cells contain free sulfur granules.
    Genus V. *Thiospira*, p. 212.
  B. Not as above.
    Genus VI. *Spirillum*, p. 212.

Genus I. **Vibrio** *Müller.**

(Müller, Vermium terrestrium et fluviatilum, *1*, 1773, 39; *Pacinia* Trevisan, Atti d. Accad. Fisio-Medico-Statistica in Milano, Ser. 4, *3*, 1885, 83; *Microspira* Schroeter, in Cohn, Kryptogamen-Flora von Schlesien, *3*, 1, 1886, 168; *Pseudospira* De Toni and Trevisan, Sylloge Fungorum, *8*, 1889, 1018; *Photobacterium* Beijerinck, Arch. néerl. d. sci. exactes, *23*, 1889, 401; *Liquidovibrio* Orla-Jensen, Cent. f. Bakt. II Abt., *22*, 1909, 333; *Solidovibrio* Orla-Jensen, *ibid.; Dicrospira* Enderlein, Sitzber. Ges. naturf. Freunde, Berlin, 1917, 313.) From Latin, *vibro*, vibrate.

Cells short, curved, single or united into spirals. Motile by means of a single polar flagellum which is usually relatively short; rarely, two or three flagella in one tuft. They grow well and rapidly on the surface of standard culture media. Aerobic to anaerobic species. Mostly water forms, a few parasites.

The type species is *Vibrio comma* (Schroeter) Winslow et al.

Key to the species of genus **Vibrio.**

I. Gelatin liquefied.
  A. Nitrites produced from nitrates.
    1. Indole is formed.
      a. Milk not coagulated.
        1. *Vibrio comma.*
        2. *Vibrio berolinensis.*
      aa. Milk coagulated.
        3. *Vibrio metschnikovii.*

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* Revised by Prof. D. H. Bergey, Philadelphia, Pennsylvania, April, 1937; partial revision by Capt. Wm. C. Haynes, Sn.C., Fort Bliss, Texas, July, 1943 and by Lt. Col. A. Parker Hitchens, University of Pennsylvania, Philadelphia, Penna., December, 1943.

2. Indole not formed.
   a. Milk not coagulated.
      4. *Vibrio tyrogenus.*
      5. *Vibrio xenopus.*

B. Nitrites not produced from nitrates.
1. Indole is formed.
   a. Milk coagulated, peptonized.
      6. *Vibrio piscium.*
2. Indole not formed.
   a. Milk acid, coagulated.
      7. *Vibrio proteus.*
      8. *Vibrio wolfii.*
      9. *Vibrio sputigenus.*
      10. *Vibrio liquefaciens.*
   aa. Milk not coagulated.
      b. Growth on potato thin, barely visible.
         11. *Vibrio strictus.*
      bb. No growth on potato.
         12. *Vibrio aquatilis.*
   aaa. Action on milk not reported.
      b. Acid from glucose. Attacks naphthalene.
         13. *Vibrio neocistes.*
      bb. No acid from carbohydrates. Attacks naphthalene.
         14. *Vibrio cuneatus.*
      bbb. No acid from carbohydrates. Liquefies agar.
         15. *Vibrio granii.*

II. Gelatin not liquefied.

A. Nitrites produced from nitrates.
1. Acid and gas from glucose.
   16. *Vibrio leonardii.*
2. Acid but not gas from glucose. Liquefies agar.
   17. *Vibrio agarliquefaciens.*

B. Nitrites not produced from nitrates.
1. Acid from glucose.
   18. *Vibrio cyclosites.*
2. No acid from carbohydrates.
   19. *Vibrio percolans.*

C. Nitrite production not reported.
1. Requires the addition of ammonium sulfate for growth. Ammonium sulfate agar liquefied.
   20. *Vibrio andoi.*
2. Do not require ammonium sulfate for growth.
   a. Indole not formed.
      b. Microaerophilic, becoming aerobic.
         21. *Vibrio fetus.*
      bb. Aerobic, facultative.
         22. *Vibrio pierantonii.*

1. **Vibrio comma** (Schroeter) Winslow et al. (Kommabacillus, Koch, Berliner klin. Wochenschr., *21*, 1884, 479; *Spirillum cholerae asiaticae* Zopf, Die Spaltpilze, 3 Aufl., 1885, 69; *Pacinia choleraeasiaticae* Trevisan, Atti d. Accad.

Fisio-Med.-Statistica in Milano, Ser. 4, *3*, 1885, 84; *Microspira comma* Schroeter, in Cohn, Kryptogamen Flora v. Schlesien, *3*, 1, 1886, 168; *Vibrio cholerae* Neisser, Arch. f. Hyg., *19*, 1893, 199; *Vibrio cholerae asiaticae* Pfeiffer, in Flügge, Die Mikroorganismen, *2*, 1896, 527; Winslow et al., Jour. Bact., *5*, 1920, 204; *Bacillus cholerae* Holland, Jour. Bact., *5*, 1920, 217; *Bacillus comma* Holland, *ibid.*, 218; *Spirillum cholerae-asiaticae* Holland, *ibid.*, 225; *Vibrio cholerae-asiaticae* Holland, *ibid.*, 226.) From Latin, comma.

Slightly curved rods, 0.3 to 0.6 by 1.0 to 5.0 microns, occurring singly and in spiral chains. Cells may be long, thin and delicate or short and thick. May lose their curved form on artificial cultivation. Motile, possessing a single polar flagellum. Gram-negative.

Gelatin colonies: Small, yellowish-white.

Gelatin stab: Rapid napiform liquefaction.

Agar colonies: Circular, whitish-brown, moist, glistening, translucent, slightly raised, entire.

Agar slant: Brownish-gray, moist, glistening.

McConkey's medium: Good growth, colonies colorless when young, soon pinkish, medium becomes darker red.

Broth: Slightly turbid, with fragile, wrinkled pellicle and flocculent precipitate.

Peptone water: Characteristic rapid growth, chiefly at surface, where after 6 to 9 hours, a delicate membrane is formed; little turbidity, deposit apparently derived from pellicle (Topley and Wilson, Princip. Bact. and Immun., 2nd ed., 1936, 388). Readily isolated from the surface film of 0.1 per cent peptone water.

Litmus milk: Alkaline at the top and slightly acid at bottom; generally not coagulated; peptonized; reduced.

Potato: Dirty-white to yellowish, moist, glistening, spreading.

Blood serum: Abundant growth, sometimes slow liquefaction.

Blood agar: The blood pigment is digested forming a greenish zone around colonies; a true soluble hemolysin is not formed (the El Tor vibrio also digests blood pigment but in addition produces a soluble hemolysin. Otherwise it is said to be indistinguishable from the typical cholera vibrio).

Indole is formed.

Nitrites produced from nitrates.

Cholera-red reaction, which depends on production of indole and reduction of nitrates is positive.

Hydrogen sulfide is formed.

Acid but not gas from glucose, fructose, galactose, maltose, sucrose and mannitol. Slowly from glycerol. Does not attack lactose, inulin or dulcitol.

Group I of Heiberg (Classification of *Vibrio cholerae* and Cholera-like Vibrios. Copenhagen, 1935) ferments mannose and sucrose but not arabinose.

Hydrolyzes starch actively in alkaline media.

High alkali but low acid tolerance; optimum pH 7.6 to 8.0; for isolation on Dieudonne's medium pH 9.0 to 9.6.

Aerobic, grows best in abundant oxygen; under strict anaerobiosis may fail to grow altogether.

Optimum temperature 37°C. Maximum 42°C. Minimum 14°C.

Source: From intestinal contents of cholera patients in Egypt and India.

Habitat: Intestinal contents of cholera patients and carriers.

The relationships existing among the cholerigenic and non-pathogenic water vibrios, although studied intensively, have not yet been completely defined. As a working scheme, based on somatic (O) and flagellar (H) antigen studies, Gardner and Vankatraman (Jour. Hyg., *35*, 1935, 262–282) suggest the following

Cholera group of vibrios.
(Biochemically similar. Common H antigen.)

O-sub-group I.

Non-hemolytic (goat cells). Cholera vibrios. Types—original, variant and middle.

Hemolytic (goat cells). El Tor vibrios. Types—original and variant (?middle).

O sub-groups II, III, IV, V, VI and individual races (mostly hemolytic). Paracholera, cholera-like, and some El Tor vibrios.
(Types within sub-groups underlined.)

Linton (Bact. Rev., *4*, 1940, 275) has outlined a classification of the vibrios based upon their protein and polysaccharide structures. Using chemical methods, it was found that one polysaccharide and one protein was commonly obtained from each strain of vibrio; when exceptions occurred, it was invariably noted that the strain was undergoing dissociation. Given a single protein and polysaccharide in each vibrio, it was possible to divide the strains into six groups, which were numbered in the order of their discovery as shown in the table.

A chemical grouping of the cholerigenic and water vibrios.

Group	Protein Type	Polysaccharide Type
I	I	I
II	I	II
III	II	II
IV	II	I
V	II	III
VI	I	III

The strains of Groups I and II possess the same protein and different polysaccharides. These are derived from cases of cholera and have the serological and biochemical characteristics of O-Group I, *Vibrio cholera*. Group I strains are more common than those of Group II, which have, however, been isolated from epidemics with a high mortality. The phospholipid fraction is common to both types when isolated in the early part of an epidemic, but is not found in strains of other groups. The harmless water vibrios, which are so heterogeneous serologically (Taylor and Ahuja, Indian Jour. Med. Res., *26*, 1938, 8–32) form a single chemical group with a homogeneous structure. They fall into Group III, which differs in its protein structure from the authentic cholera vibrios, and resembles Group II in its polysaccharide. The vibrios of Group IV, which came from El Tor and from chronic vibrio carriers are believed on epidemiological grounds to be harmless, although serological methods have failed to distinguish them from cholerigenic vibrios. Group V, which, like III and IV, contains protein II, consists, like Group IV, of strains from chronic vibrio carriers. Group VI strains are only rarely isolated in nature and representatives of this group are generally found among collections of old laboratory strains. They appear to be the result of polysaccharide variation from Group I

after long-continued growth on artificial media.

2. **Vibrio berolinensis** Neisser. (Arch. f. Hyg., *19*, 1893, 200; *Microspira berolinensis* Migula, in Engler and Prantl, Die natürl. Pflanzenfam., *1*, 1a, 1895, 33.) From M. L., the genitive of *Berolina*, the Latin name for Berlin.

Curved rods, somewhat smaller than *Vibrio comma*. Frequently occurring in pairs. Motile, possessing a polar flagellum. Pleomorphic. Gram-negative.

Gelatin colonies: Small, grayish, slightly granular, fragmented.

Gelatin stab: Slow, napiform liquefaction.

Agar slant: Grayish-yellow, moist, glistening.

Broth: Turbid, with gray pellicle.

Litmus milk: No coagulation, no acid.

Potato: Brownish streak.

Indole is formed.

Nitrites produced from nitrates.

Not pathogenic for mice, pigeons or guinea pigs.

Aerobic, facultative.

Optimum temperature 37°C. Minimum above 10°C. Maximum less than 60°C.

Source: Isolated from filtered Spree river water.

3. **Vibrio metschnikovii** Gamaléia. (Gamaléia, Ann. Inst. Pasteur, *2*, 1888, 482; *Pacinia metschnikoffi* Trevisan, I generi e le specie delle Batteriacee, 1889, 23; *Spirillum metschnikovi* Sternberg, Man. of Bact., 1893, 511; *Vibrio nordhafen* Pfuhl, Ztschr. f. Hyg., *22*, 1894, 234; *Microspira metschnikoffii* Migula, in Engler and Prantl, Die natürl. Pflanzenfam., *1*, 1a, 1895, 33.) Named for Metschnikoff, Russian bacteriologist.

Probable synonyms: *Vibrio schuylkiliensis* Abbott, Jour. Exp. Med., *1*, 1896, 424 (*Microspira schuylkiliensis* Chester, Manual Determ. Bact., 1901, 334); *Vibrio danubicus* Heider, Cent. f. Bakt., *14*, 1893, 341 (*Microspira danubica* Migula in Engler and Prantl, Die natürl. Pflanzenfam., *1*, 1a, 1895, 33; *Spirillum danubicum* Holland, Jour. Bact., *5*, 1920, 225).

Curved rods, somewhat shorter and thicker than *Vibrio comma*. Motile. Gram-negative.

Gelatin colonies: Like those of *Vibrio comma*.

Gelatin stab: Rapid, napiform liquefaction.

Agar slant: Yellowish, plumose, moist, glistening.

Broth: Turbid, with thin, white pellicle.

Litmus milk: Acid, coagulated (eighth day); not peptonized.

Potato: Delicate, brownish growth.

Indole is formed.

Nitrites produced from nitrates.

Pathogenic for pigeons, fowls, and guinea pigs.

Aerobic, facultative.

Optimum temperature 37°C. Maximum less than 45°C.

Source: Isolated from fowl dead of a choleraic disease.

Habitat: The intestinal contents of chickens, pigeons and other animals suffering from a cholera-like disease.

4. **Vibrio tyrogenus** (Flügge) Holland. (Käsespirillen, Deneke, Deutsch. med. Wochnschr., *11*, 1885, 33; *Spirillum tyrogenum* Flügge, Die Mikroorganismen, 2 Aufl., 1886, 386; *Pacinia denekei* Trevisan, I generi e le specie delle Batteriacee, 1889, 23; *Microspira tyrogena* Migula, in Engler and Prantl, Die natürl. Pflanzenfam., *1*, 1a, 1895, 33; Holland, Jour. Bact., *5*, 1920, 225; *Vibrio denekei* Hauduroy et al., Dict. d. Bact. Path., 1937, 541.) From Greek *tyros*, cheese; *genes*, produced from.

Curved rods, rather smaller and more slender than *Vibrio comma*, often very long, closely wound spirals. Motile, possessing a polar flagellum. Gram-negative.

Gelatin colonies: Small, gray, granular, entire.

Gelatin stab: Rapid, saccate liquefaction.

Agar slant: Yellowish-white, plumose, glistening.

Broth: Turbid.

Litmus milk: Not coagulated.

Potato: No growth.

Indole not formed.

Slight production of nitrites from nitrates.

Aerobic, facultative.

Optimum temperature 30°C.

Source: Isolated from cheese.

5. **Vibrio xenopus** Schrire and Greenfield. (Trans. Royal Soc. So. Africa, *17*, 1930, 309.) From *Xenopus*, a genus of African toads.

Spiral forms, occurring singly and in pairs. Non-motile. Gram-negative.

Gelatin stab: Slow, crateriform liquefaction.

Agar colonies: Small, white, glistening, slimy, entire.

Agar slant: Grayish-white, slimy, entire.

Broth: Turbid with flocculent sediment.

Litmus milk: Unchanged.

Potato: Not reported.

Indole is not formed.

Nitrites are produced slowly from nitrates.

Blood serum is peptonized.

Starch is not hydrolyzed.

Acid from glucose, fructose, maltose, glycerol and sorbitol.

Aerobic, facultative.

Optimum temperature 37°C.

Source: Found in abscess of pectoral muscle of African toad.

6. **Vibrio piscium** David. (Cent. f. Bakt., I Abt., Orig., *102*, 1927, 46.) From Latin *piscis*, fish.

Curved rods: 0.3 to 0.5 by 2.0 microns. Motile with a single polar flagellum. Gram-negative.

Gelatin colonies: Circular, granular, opaque.

Gelatin stab: Napiform liquefaction.

Agar colonies: Yellowish, circular, smooth, entire, iridescent.

Agar slant: Light yellow, transparent streak.

Broth: Slight turbidity, with thin pellicle.

Litmus milk: Soft coagulum. Peptonized, alkaline.

Potato: Brownish-red streak.

Indole is formed.

Nitrites not produced from nitrates.

Hydrogen sulfide formed.

No action in sugar media.

Pathogenic for frogs.

Aerobic, facultative.

Optimum temperature 18° to 20°C.

Habitat: Causes epidemic infection in fish.

7. **Vibrio proteus** Buchner. (Kommabacillus der cholera nostras, Finkler and Prior, Deutsche med. Wochenschr., 1884, 632; Buchner, Sitzungsber. d. Gesel. f. Morph. u. Physiol., München, Heft 1, 1885, 10; *Pacinia finkleri* Trevisan, Atti d. Accad. Fisio-Medico-Statistica in Milano, Ser. 4, *3*, 1885, 84; *Microspira finkleri* Schroeter, in Cohn, Krytogamen-Flora von Schlesien, *3*, 1, 1886, 168; *Spirillum finkleri* Crookshank, Man. of Bact., 3rd ed., 1890, 282; *Microspira protea* Chester, Manual of Determinative Bacteriology, 1901, 338; *Vibrio finkleri* Holland, Jour. Bact., *5*, 1920, 225.) From Greek, *Proteus*, a marine deity who had the power of assuming any shape he chose.

Curved rods: 0.4 to 0.6 by 2.4 microns, often pointed at both ends. Motile, possessing a polar flagellum. Gram-negative.

Gelatin colonies: Small, gray, circular, granular, entire.

Gelatin stab: Rapid, saccate liquefaction.

Agar slant: Dirty grayish, plumose.

Broth: Turbid, with fetid odor.

Litmus milk: Slightly acid; coagulated; peptonized.

Potato: Grayish, slimy layer.

Indole not formed.

Nitrites not produced from nitrates.

Aerobic, facultative.

Optimum temperature 30°C.

Source: Isolated from feces of patients suffering from cholera nostras.

Habitat: Intestinal contents in cholera nostras and cholera infantum.

8. **Vibrio wolfii** (Migula) Bergey et al. (*Bacillus choleroides* Wolf, Münch. med. Wochenschr., *40*, 1893, 693; *Microspira wolfii* Migula, Syst. d. Bakt., *2*, 1900, 1001; not *Microspira choleroides* Migula, *loc. cit.*, 992; Bergey et al., Manual, 1st ed., 1923, 80.) Named for Wolf, who first isolated this organism.

Curved rods and S-shaped forms. Motile. Gram-negative.

Gelatin colonies: Small, grayish-white, spreading.

Gelatin stab: Infundibuliform liquefaction.

Agar slant: Gray, moist layer.

Broth: Turbid, with gray pellicle.

Litmus milk: Acid; coagulated.

Potato: Yellowish-white layer.

Blood serum: Rapid liquefaction.

Indole not formed.

Nitrites not produced from nitrates.

Aerobic, facultative.

Optimum temperature 37°C.

Source: Isolated from cervical secretions in chronic endometritis.

9. **Vibrio sputigenus** (Migula) Bergey et al. (Vibrio aus Sputum, Brix, Hyg. Rundschau, *4*, 1894, 913; *Microspira sputigena* Migula, Syst. d. Bakt., *2*, 1900, 981; Bergey et al., Manual, 1st ed., 1923, 80.) From Latin, *spuo* (*sputus*), sputum; *-genes*, produced from.

Slightly curved rods, about the same size and form as *Vibrio comma*, occurring singly, occasionally three or four in a chain. Motile. Possessing a polar flagellum. Gram-negative.

Gelatin colonies: Small, circular, slightly granular, yellowish, becoming brownish.

Gelatin: Crateriform liquefaction.

Agar slant: Grayish-white, moist.

Broth: Turbid, no pellicle formed.

Litmus milk: Acid; coagulated.

Potato: Thin, gray layer, spreading.

Indole not formed.

Nitrites not produced from nitrates.

Aerobic, facultative.

Optimum temperature 37°C.

Source: Isolated from sputum.

10. **Vibrio liquefaciens** (Migula) Bergey et al. (Bonhoff, Arch. f. Hyg., *19*, 1893, 248; *Microspira liquefaciens* Migula, Syst. d. Bakt., *2*, 1900, 990; Bergey et al., Manual, 1st ed., 1923, 81.) From Latin, *liquefacio*, to make liquid.

Comma and S-shaped rods. Motile. Gram-negative.

Gelatin colonies: Circular, with irregular margin, surrounded by a rose-colored zone.

Gelatin stab: Slow, napiform liquefaction.

Agar slant: Smooth, grayish, plumose.

Broth: Turbid, with heavy grayish pellicle.

Litmus milk: Acid; coagulated.

Potato: Moist, brownish layer.

Indole is not formed.

Nitrites not produced from nitrates.

Aerobic, facultative.

Optimum temperature 37°C.

Habitat: Water.

11. **Vibrio strictus** Kutscher. (Ztschr. f. Hyg., *19*, 1895, 469.) From Latin *stringo* (*strictus*), constricted.

Markedly curved rods, of about twice the size of *Vibrio comma*. Motile. Gram-negative.

Gelatin colonies: Small, circular, yellowish, with serrate margin.

Gelatin stab: Slow, napiform to saccate liquefaction.

Agar slant: Growth plumose, moist.

Broth: Turbid, with gray pellicle.

Litmus milk: Not coagulated.
Potato: Thin, barely visible layer.
Blood serum is slowly liquefied.
Indole is not formed.
Nitrites not produced from nitrates.
Pathogenic for guinea pigs.
Aerobic, facultative.
Optimum temperature 37°C.
Habitat: Water.

12. **Vibrio aquatilis** Günther. (Deutsche med. Wochenschr., 1892, 1124; *Microspira aquatilis* Migula, System der Bakterien, *2*, 1900, 993.) From Latin, *aquaticus*, living in water.

Curved rods, like *Vibrio comma*. Motile, possessing a polar flagellum. Gram-negative.

Gelatin colonies: Circular, brownish, finely granular, entire.

Gelatin stab: Crateriform liquefaction.
Agar slant: Moist, grayish, glistening.
Broth: Slightly turbid.
Litmus milk: Not coagulated.
Potato: No growth.
Indole not formed.
Nitrites not produced from nitrates.
Aerobic, facultative.
Optimum temperature 30°C.
Habitat: Water.

13. **Vibrio neocistes** Gray and Thornton. (Gray and Thornton, Cent. f. Bakt., II Abt., *73*, 1928, 92.) From Greek *néos*, new and *kistē* box or ark. Here used as the equivalent of Newark, the name of a city in England.

Curved rods: 0.5 to 1.0 by 1.0 to 4.0 microns. Motile with one to three polar flagella. Gram stain not recorded.

Gelatin colonies: Liquefied.

Gelatin stab: Liquefied. Medium reddened.

Agar colonies: Circular or amoeboid, buff to brownish, convex, smooth, glistening, entire.

Agar slant: Filiform, fluorescent, raised, smooth, glistening, undulate.

Broth: Turbid.
Nitrites not produced from nitrates.
Starch not hydrolyzed.
Acid from glucose.
Attacks naphthalene.
Aerobic, facultative.
Optimum temperature.
Habitat: Soil.

14. **Vibrio cuneatus** Gray and Thornton. (Gray and Thornton, Cent. f. Bakt., II Abt., *73*, 1928, 92.) From Latin, *cuneo* (*cuneatus*) wedge.

Curved rods: 1.0 by 1.0 to 3.0 microns, the cells tapering at one extremity. Motile with one to five polar flagella. Gram-negative.

Gelatin colonies: Liquefied.

Gelatin stab: Liquefied.

Agar colonies: Circular to amoeboid, white to buff, flat to convex, smooth, translucent, border entire.

Agar slant: Filiform, whitish, smooth, glistening.

Indole not recorded.
Nitrites not produced from nitrates.
Starch not hydrolyzed.
No acid from carbohydrate media.
Attacks naphthalene.
Aerobic, facultative.
Optimum temperature 30° to 35°C.
Source: One strain isolated from soil from Rothamsted, England.
Habitat: Soil.

15. **Vibrio granii** (Lundestad) Stanier. (*Bacterium granii* Lundestad, Cent. f. Bakt., II Abt., *75*, 1928, 330; *Achromobacter granii* Bergey et al., Manual, 3rd ed., 1930, 222; Stanier, Jour. Bact., *42*, 1941, 538.) Named for Prof. H. H. Gran, who first detected agar-liquefying bacteria.

Rods: 0.6 to 0.8 by 1.4 to 2.4 microns, with rounded ends, occurring singly, in pairs, and at times in short chains. Motile. Polar flagellate (Stanier, *loc. cit.*). Gram-negative.

Fish-gelatin colonies: Punctiform, black, glistening.

Fish-gelatin stab: Slow, crateriform liquefaction.

Sea-weed agar colonies: Circular, flat

opaque, glistening, white, slimy, entire. Agar is dissolved.

Fish-agar slant: Flat, white, elevated, glistening, undulate. Liquefied.

Broth: Turbid with grayish-white, slimy sediment.

Indole not formed.

Nitrites not produced from nitrates.

Starch usually hydrolyzed.

No action on sugars.

Aerobic, facultative.

Optimum temperature 20° to 25°C.

Source: Sea water of Norwegian Coast.

Habitat: Presumably sea water and on sea weeds.

16. **Vibrio leonardii** Métalnikov and Chorine. (Ann. d. l'Inst. Pasteur, *42*, 1928, 1647.) Named for Leonard.

Curved rods with rounded ends, 0.5 to 1.0 by 2.0 to 3.0 microns. Motile with 1 to 3 polar flagella. Gram-negative.

Gelatin stab: No liquefaction.

Agar colonies: Small, transparent, circular, having a characteristic odor.

Broth: Turbid, with thin pellicle.

Litmus milk: No coagulation, acid, with reduction of litmus.

Potato: Slight, colorless growth.

Indole not formed.

Nitrites produced from nitrates.

Blood serum not liquefied.

Hydrogen sulfide formed.

Acid and gas from glucose, fructose, galactose, lactose, sucrose and mannitol. No acid or gas from maltose or glycerol.

Aerobic, facultative.

Optimum temperature 30°C.

Habitat: Highly pathogenic for insects as *Galleria mellonella* L. (bee moth), and *Pyrausta nubialis* Hübn. (European corn borer).

17. **Vibrio agarliquefaciens** (Gray and Chalmers) Bergey et al. (*Microspira agar-liquefaciens* Gray and Chalmers, Ann. Appl. Biol., *11*, 1924, 325; Manual, 4th ed., 1934, 119.) From Latin, *liquefacio*, liquefying; Malay, *agar*, a jelly from seaweeds.

Short curved rods, usually c-shaped, with occasional s-shaped and coccoid forms. Cells 2.0 microns long by 0.5 to 0.7 micron broad; 3.0 to 5.0 microns long in division stages. Coccoid forms stained, 0.5 to 0.7 micron long. Motile with a single polar flagellum. Gram stain not reported.

Gelatin stab: Very slight surface growth after one month; the streak then shows a beaded line. No liquefaction.

Agar colonies: Surface colonies appear as a whitish growth in a depression, surrounded by a white ring. The colony is later surrounded by a ring of liquid agar. Deep colonies show a clear area and may be irregular, oval or angular.

Agar slant: A deep groove is cut along the inoculation streak, whitish growth along sides. The gel is later much weakened.

Broth: Slightly turbid. No pellicle.

Acid from glucose, lactose and maltose. No acid from sucrose or glycerine.

Utilizes ammonia salts as a source of nitrogen.

Decomposes cellulose and agar. The presence of one per cent glucose prevents the liquefaction of agar.

Nitrites produced from nitrates.

Starch is hydrolyzed.

Aerobic.

Temperature relations: Optimum 25° C., will grow at 16° but not at 34°C.

Habitat: Soil.

18. **Vibrio cyclosites** Gray and Thornton. (Gray and Thornton, Cent. für Bakt., II Abt., *73*, 1928, 92.) From Greek *kyklos*, circle or ring; *sītéō*, to eat; M. L. *cyclosites*, feeding on rings, i.e. ring compounds.

Curved rods: 0.5 to 1.0 by 1.5 to 4.0 microns. Motile with a single polar flagellum. Gram-negative.

Gelatin colonies: Circular, buff to brown, flat, smooth, glistening, entire.

Gelatin stab: No liquefaction.

Agar colonies: Circular to irregular, pale buff (later greenish), smooth, entire.

Agar stab: Filiform, greenish buff, raised, smooth, undulate.

Broth: Turbid.
Indole not reported.
Nitrites not produced from nitrates.
Starch not hydrolyzed.
Acid from glucose.
Attacks phenol and *m*-cresol.
Aerobic, facultative.
Optimum temperature 30° to 35°C.
Habitat: Soil.

19. **Vibrio percolans** Mudd and Warren. (Jour. of Bact., *8*, 1923, 447.) From Latin, *percolo* (*percolatus*), filtering.

Curved rods: 0.3 to 0.4 by 1.5 to 1.8 microns, occurring singly or in short chains. Pleomorphic. Actively motile by means of 1 to 3 polar flagella. Gram-negative.

Gelatin stab: No liquefaction.

Agar colonies: Circular, slightly convex, amorphous, entire.

Agar slant: Bluish-white, glistening, streak.

Broth: Turbid. Pellicle, sediment.
Litmus milk: Unchanged.
Potato: White, slimy streak.
Indole not formed.
Nitrites not produced from nitrates.
Blood serum not liquefied.
Starch not hydrolyzed.
No action on carbohydrates.
Passes through bacterial filters.
Aerobic, facultative.
Optimum temperature 30°C.
Non-pathogenic.
Source: Isolated from hay infusion.
Habitat: Water.

20. **Vibrio andoi** Aoi and Orikura. (Cent. f. Bakt., II Abt., *74*, 1928, 331.) Named for Andoi, a Japanese scientist.

Curved rods, with more or less tapering ends, c- or s-shaped, 0.5 to 0.8 by 1.5 to 2.5 microns. Motile, with a single polar flagellum. Gram-negative.

Gelatin: No growth.
Agar media: No growth.
Broth: No growth.
Litmus milk: No growth.
Potato: No growth.

Ammonium sulfate agar colonies: Punctiform, circular, concave, surrounded with clear zone.

Ammonium sulfate agar slant: Grayish, becoming straw-yellow, sinking into the medium as the agar liquefies.

Cellulose media: No growth.
Starch hydrolyzed.

Glucose, fructose, galactose, mannose, xylose and "honyak" are fermented.

Xylan is decomposed.
Cellobiose is decomposed.
Aerobic, facultative.

Optimum temperature 25°C. Minimum 8°C. Maximum 37°C.

Source: Rotted stable manure.

Habitat: Presumably decomposing organic matter.

21. **Vibrio fetus** Smith and Taylor. (*Spirillum* causing abortion in sheep, MacFadyean and Stockman, Rept. Dept. Comm. Ministry Agric. on Epizootic Abortion, London, 1909, 156; *ibid.*, 1913, 111; *Spirillum* associated with infectious abortion, Smith, Jour. Exp. Med., *28*, 1918, 701; Smith and Taylor, *ibid.*, *30*, 1919, 299; *Spirillum fetus* Lehmann and Neumann, Bakt. Diag., 7 Aufl., *2*, 1927, 552; *Vibrio foetus ovis* Buxton, First Rept. of Director, Univ. Cambridge Instit. Animal Pathol., 1929–1930, 47.) From L. *foetus*, fetus.

Curved rods: The smallest forms appear as minute curved s-shaped lines, other forms very long; 0.2 to 0.5 by 1.5 to 5.0 microns. Motile by means of one, rarely two, polar flagella. Occasionally forms capsules. Granules present in older cultures. Gram-negative.

Gelatin: No growth.

Agar slant: No surface growth by freshly isolated strains. Laboratory strains produce a scanty, grayish-white, glistening surface growth.

Subsurface agar colonies: Small, yellow, opaque.

Broth: A viscid ring pellicle may appear, faint clouding of the medium occurs; a filmy, stringy deposit may settle out.

Litmus milk: No growth

Potato: No growth.

Indole not formed.

Nitrite production not reported.

Blood serum slant: Feeble growth. No liquefaction.

No gas from carbohydrates. No change or slightly acid from glucose, lactose and sucrose.

Optimum temperature 37°C. Withstands 55°C for 5 minutes.

Aerobic or microaerophilic.

Pathogenesis: Causes abortion in cattle.

Source: Twenty-two strains isolated from the placentas or fetuses of cows having abortion.

Habitat: Causes abortion in cattle.

22. **Vibrio pierantonii** (Zirpolo) Meissner. (*Bacillus pierantonii* Zirpolo, Boll. Soc. nat. Napoli, *30*, 1918, 206; Meissner, Cent. f. Bakt., II Abt., *67*, 1926, 200.) Named for Pierantoni, an Italian bacteriologist.

Rods: 0.5 by 1.5 microns, with rounded ends. Motile with one to three polar flagella. Gram-negative.

Gelatin colonies: Circular, and irregularly lobulate.

Gelatin stab: No liquefaction.

Agar colonies: Circular, light green, smooth, entire.

Glycerin agar slant: Slightly luminous streak.

Broth: Turbid, with pellicle.

Indole not formed.

Acid from glucose and maltose. Some strains also attack lactose, sucrose and mannitol.

Best growth in alkaline media.

Aerobic, facultative.

Optimum temperature 37°C.

Source: Isolated from the photogenic organ of the cephalopod *Sepiola intermedia* Naef.

Appendix:* The following species have also been listed in the literature. Many are inadequately described.

Microspira bonhoffii Migula. (Bonhoff, Arch. f. Hyg., *19*, 1893, 252; Migula, Syst. d. Bakt., *2*, 1900, 1008.) From water.

Microspira canalis Migula. (*Spirillum saprophiles* γ and *Vibrio saprophiles* γ Weibel, Cent. f. Bakt., *2*, 1887, 469; Migula, Syst. d. Bakt., *2*, 1900, 1004; *Microspira cloaca* Chester, Man. Determ. Bact., 1901, 341.) Possibly identical with *Microspira saprophiles* Migula, *Microspira weibelii* Migula, *Vibrio surati* Ford, *Vibrio smithii* Ford. From sewage.

Microspira coprophila Migula. (Group 3, No. 6, Kutscher, Ztschr. f. Hyg., *19*, 1895, 475; Migula, Syst. der Bakt., *2*, 1900, 986.) From fecal matter.

Microspira maasei (v. Hoff) Migula. (*Spirillum maasei* v. Hoff, Cent. f. Bakt., I Abt., *21*, 1897, 797; Migula, Syst. d. Bakt., *2*, 1900, 978.) Possibly a variety of *Vibrio comma* Winslow et al. From Rotterdam tap water.

Microspira milleri Migula. (Miller, Deutsche med. Wehnschr., *11*, 1885, 138; Migula, Syst. d. Bakt., *2*, 1900, 981; *Spirillum milleri* Holland, Jour. Bact., *5*, 1920, 225; *Vibrio milleri* Holland, *ibid.*) Probably identical with *Vibrio proteus* according to Migula. From dental caries.

Microspira murmanensis Issatchenko. (Recherches sur les microbes de l'océan glacial arctique (in Russian), Petrograd, 1914, 240.) From sea water.

Microspira saprophiles Migula. (Heuvibrio β, Weibel, Cent. f. Bakt., *2*, 1887, 469; *Vibrio saprophiles* β Weibel, Cent. f. Bakt., *4*, 1888, 225; Migula, Syst. d. Bakt., *2*, 1900, 1006; *Microspira weibeli* Chester, Man. Determ. Bact., 1901, 230.) Probably identical with *Microspira cloaca* Chester and *Vibrio surati* Ford. From sewage.

Microspira tyrosinatica Beijerinck. (Kon. Akad. Wetenschappen, Amsterdam, *13*, 1911, 1068.) From sewage.

Microspira weibelii Migula. (*Vibrio*

*** Prepared by Mr. Wm. C. Haynes, New York State Experiment Station, Geneva, New York, Jan., 1939; Revised by Capt. Wm. C. Haynes, Sn. C., Fort Bliss, Texas, July, 1943.**

saprophiles α Weibel, Cent. f. Bakt., *2*, 1887, 465; *ibid.*, *4*, 1888, 225; Migula, Syst. d. Bakt., *2*, 1900, 1005; *Microspira saprophile* Chester, Manual Determ. Bact., 1901, 341; *Vibrio saprophiles* Ford, Textb. of Bakt., 1927, 356.) Possibly identical with *Microspira cloaca* Chester, *Vibrio surati* Ford, *Vibrio smithii* Ford. From sewage.

Spirillum lipoferum Beijerinck. (Cent. f. Bakt., II Abt., *63*, 1925, 353; *Chromatium lipoferum* Bergey et al., Manual, 3rd ed., 1930, 531.) From garden earth and sewage. Giesberger (Beiträge zur Kenntnis der Gattung *Spirillum* Ehbg., Inaug. Diss., Delft, 1936, 64) regards this organism as a *Vibrio*. Has a single polar flagellum.

Spirillum nasicola Trevisan. (Nasenschleimvibrio, Weibel, Cent. f. Bakt., *2*, 1887, 465; Trevisan, I generi e le specie delle Batteriacee, 1889, 24; *Vibrio nasalis* Eisenberg, Bakt. Diag., 3 Aufl., 1891, 213; *Spirillum nasale* Sternberg, Man. of Bact., 1893, 697; *Spirosoma nasale* Migula, in Engler and Prantl, Die natürl. Pflanzenfam., *1*, 1 a, 1895, 31.) From human nasal mucus.

Spirillum parvum Esmarch. (Cent. f. Bakt., I Abt., Orig., *32*, 1902, 565; also see Zettnow, *ibid.*, *78*, 1916, 1; *Vibrio parvus* Lehmann and Neumann, Bakt. Diag., 4 Aufl., *2*, 1907, 494.) From decaying organic matter.

Vibrio albensis Lehmann and Neumann. (Elbe vibrio, Dunbar, Deutsch. med. Wochnschr., *19*, 1893, 799; Lehmann and Neumann, Bakt. Diag., 1 Aufl., *2*, 1896, 340; *Microspira dunbari* Migula, Syst. d. Bakt., *2*, 1900, 1013; *Photospirillum dunbari* Miquel and Cambier, Traité de Bact., Paris, 1902, 881; *Photobacterium dunbari* Ford, Textb. of Bakt., 1927, 621.) From water of the river Elbe. Phosphorescent.

Vibrio amylocella Gray. (Canad. Jour. Res., *17*, 1939, 154.) Decomposes cellulose. Produces glucose from starch. From soil.

Vibrio anguillarum Bergman. (Ber. a. d. k. Bayr. Biolog. Versuchstat., München, *2*, 1909.) From an infectious disease of eels.

Vibrio aureus Weibel. (Weibel, Cent. f. Bakt., *4*, 1888, 225, 257, 281; *Spirillum aureum* Trevisan, I generi e le specie delle Batteriacee, 1889, 24; *Spirillum aureum* Sternberg, Man. of Bact., 1893, 700; *Spirosoma aureum* Migula, Syst. d. Bakt., *2*, 1900, 958.) Possibly identical with *Vibrio flavus* Weibel and *Vibrio flavescens* Weibel. From sewage.

Vibrio beijerinckii Stanier. (Jour. Bact., *42*, 1941, 527–554.) Marine agar-digesting vibrio.

Vibrio buccalis Prévot. (Vibrion B, Repaci, Compt. rend. Soc. Biol., Paris, 1909, 630; Prévot, Man. de Classif. des Bact. Anaér., Paris, 1940, 82.) Anaerobe. From the buccal cavity.

Vibrio bulbosa Kalniņš. (Latvijas Ūniversitātes Raksti, Serija I, No. 11, 1930, 237.) Decomposes cellulose. From soil.

Vibrio cardii Klein. (Cent. f. Bakt., I Abt., Orig., *38*, 1905, 173.) Possibly identical with *Vibrio cuneatus* Gray and Thornton and *Vibrio marinus* Ford. From the mussel (*Cardium edule*).

Vibrio castra Kalniņš. (Latvijas Ūniversitātes Raksti, Serija I, No. 11, 1930, 241.) Decomposes cellulose. From soil.

Vibrio choleroides α and *β* Bujwid. (Cent. f. Bakt., *13*, 1893, 120; *Microspira choleroides* Migula, Syst. d. Bakt., *2*, 1900, 992.) Probably a less vigorous strain of *Vibrio comma* Winslow et al. according to Chester, Man. Determ. Bact., 1901, 337. From water.

Vibrio chrysanthemoides Lehmann and Neumann. (Spirillum-like organism, Jones, Cent. f. Bakt., II Abt., *14*, 1904, 459; Lehmann and Neumann, Bakt. Diag., 4 Aufl., *2*, 1907, 493.) From five samples of tap water and sewage.

Vibrio crassus (Veillon and Repaci) Prévot. (*Spirillum crassum* Veillon and Repaci, Ann. Inst. Past., *26*, 1912, 306; Prévot, Man. de Classif. des Bact. Anaér., Paris, 1940, 85.) Anaerobe. From the buccal cavity.

Vibrio crassus var. D, Prévot. (Spirille

D, Repaci, Ann. Inst. Past., *26*, 1912, 550; Prévot, Man. de Classif. des Bact. Anaér., Paris, 1940, 86.) Anaerobe. From the buccal cavity.

Vibrio crasteri Hauduroy et al. (Craster, in Violle, Le Choléra, Masson édit., 1919; Hauduroy et al., Dict. d. Bact. Path., 1937, 541.) Isolated from healthy persons. Resembles *Vibrio comma*.

Vibrio cucumis Kalniņš. (Latvijas Ūniversitātes Raksti, Serija I, No. 11, 1930, 243.) Decomposes cellulose. From soil.

Vibrio devorans Beijerinck. (Cent. f. Bakt., II Abt., *11*, 1903, 598.) From water.

Vibrio drennani Chalmers and Waterfield. (Drennan, Jour. Inf. Dis., *14*, 1914, 251; Chalmers and Waterfield, Jour. Trop. Med., *19*, 1916, 165.) Colonies white, turning dark brown. From feces.

Vibrio flavescens Weibel. (Cent. f. Bakt., *4*, 1888, 225, 257, 281; *Spirillum flavescens* Trevisan, I generi e le specie delle Batteriacee, 1889, 24; *Spirillum flavescens* Sternberg, Man. of Bact., 1893, 700; *Spirosoma flavescens* Migula, Syst. d. Bakt., *2*, 1900, 959.) Possibly identical with *Vibrio aureus* Weibel and *Vibrio flavus* Weibel. From sewage.

Vibrio flavus Weibel. (Cent. f. Bakt., *4*, 1888, 225, 257, 281; *Spirillum flavum* Trevisan, I generi e le specie delle Batteriacee, 1889, 24; *Spirillum flavum* Sternberg, Man. of Bact., 1893, 700; *Spirosoma flavum* Migula, Syst. d. Bakt., *2*, 1900, 959.) Possibly identical with *Vibrio aureus* Weibel and *Vibrio flavescens* Weibel. From sewage.

Vibrio fuscus Stanier. (Jour. Bact., *42*, 1941, 540.) Marine agar-digesting vibrio.

Vibrio gauducheau Hauduroy et al. (Gauducheau, in Violle, Le Choléra, Masson édit., 1919; Hauduroy et al., Dict. d. Bact., 1937, 543.) From the blood of a fever patient. Resembles *Vibrio comma*.

Vibrio ghinda Pfeiffer. (Pasquale, Gior. med. d. r. esercito, 1891; Pfeiffer, in Flügge, Die Mikroörganismen, *2*, 1896, 590; *Microspira ghinda* Migula, Syst. d. Bakt., *2*, 1900, 996.) From water.

Vibrio grossus (Migula) Ford. (Vibrio No. 1, Kutscher, Ztschr. f. Hyg., *20*, 1895, 46; *Microspira grossa* Migula, Syst. d. Bakt., *2*, 1900, 1012; Ford, Textb. of Bact., 1927, 343.) From liquid manure.

Vibrio halobicus desulfuricans Horowitz-Wlassowa and Sonntag. (Arb. a. d. Staatl. wissensch. Nahrungsmittel-Institut 1931 (Russian); see Ztschr. f. Unters. d. Lebensm., *62*, 1931, 597.) A halophilic vibrio found in salted sardines, anchovies and other marine fish.

Vibrio helcogenes Fischer. (Cent. f. Bakt., *14*, 1894, 73; *Microspira helcogenes* Migula, Syst. d. Bakt., *2*, 1900, 978.) From descriptions, indistinguishable from *Vibrio proteus* according to Chester, Man. Determ. Bact., 1901, 339. From feces.

Vibrio hyos Ford. (Vibrio No. 3, Kutscher, Ztschr. f. Hyg., *20*, 1895, 46; *Spirillum mobile* Migula, Syst. d. Bakt., *2*, 1900, 1020; Ford, Textb. of Bact., 1927, 342.) Isolated from liquid manure.

Vibrio iners Besson, Ranque and Senez. (Compt. rend. Soc. Biol. Paris, *79*, 1918, 1097.) From the feces of persons having dysentery.

Vibrio intermedius (Migula) Ford. (Group V, No. 9 of cholera-like vibrios, Kutscher, Ztschr. f. Hyg., *20*, 1895, 481; *Microspira intermedia* Migula, Syst. d. Bakt., *2*, 1900, 967; Ford, Textb. of Bact., 1927, 342.) Possibly identical with *Vibrio berolinensis* Neisser. From water.

Vibrio ivanoff Pfeiffer. (Ivanoff, Ztschr. f. Hyg., *15*, 1893, 134; Pfeiffer, in Flügge, Die Mikroörganismen, *2*, 1896, 592.) Probably a variety of *Vibrio comma* Winslow et al. according to Chester, Man. Determ. Bact., 1901, 337. From feces of a cholera patient.

Vibrio jejuni Jones, Orcutt and Little. (Jour. Exp. Med., *53*, 1931, 853.) From small intestine of calves suffering from diarrhea.

Vibrio kegallensis Hauduroy et al.

(Dict. d. Bact. Path., 1937, 544.) From water.

Vibrio klimenko Hauduroy et al. (Klimenko, in Violle, Le Choléra, Masson édit., 1919; Hauduroy et al., Dict. d. Bact. Path., 1937, 544.) Resembles *Vibrio comma*. From the intestine.

Vibrio leidensis Horst. (Inaug. Diss., Leiden, 1921; abst. in Cent. f. Bakt., I Abt., Ref., *73*, 1922, 282.) From a liver abscess.

**Vibrio lingualis* Eisenberg. (Zungenbelag-Vibrio, Weibel, Cent. f. Bakt., *4*, 1888, 227; Eisenberg, Bakt. Diag., 3 Aufl., 1891, 212; *Spirillum linguae* Sternberg, Man. of Bact., 1893, 697; *Spirosoma linguale* Migula, in Engler and Prantl, Die natürl. Pflanzenfam., *1*, 1 a, 1895, 31.) From deposit on the tongue.

Vibrio lissabonensis Pestana-Bettencourt. (Cent. f. Bakt., *16*, 1894, 401.) According to Chantemesse identical, or nearly so, with *Vibrio proteus*. From descriptions, indistinguishable from *Vibrio proteus* according to Chester, Man. Determ. Bact., 1901, 339. From feces of a cholera patient.

Vibrio malamoria Kalniņš. (Latvijas Ūniversitātes Raksti, Serija I, No. 11, 930, 250.) Decomposes cellulose. From soil.

Vibrio marinus (Russell) Ford. (*Spirillum marinum* Russell, Ztschr. f. Hyg., *11*, 1891, 165; *Microspira marina* Migula, Syst. d. Bakt., *2*, 1900, 1002; Ford, Textb. of Bact., 1927, 347.) From sea water. Closely resembles *Vibrio cuneatus* Gray and Thornton and *Vibrio cardii* Klein.

Vibrio massauah Pfeiffer. (Pasquale, Gior. med. d. r. esercito, 1891; Pasquale, Baumgarten's Jahresberichte, *7*, 1891, 336; Pfeiffer, in Flügge, Die Mikroörganismen, *2*, 1896, 589; *Microspira massauah* Migula, Syst. d. Bakt., *2*, 1900, 963; *Spirillum massauah* Chester, Manual Determ. Bact., 1901, 343; *Spirillum massowah* Holland, Jour. Bact., *5*, 1920, 225; *Vibrio massowah* Holland, *ibid.*) From feces of a cholera patient.

Vibrio mulieris Prévot. (Man. de Classif. des Bact. Anaér., Paris, 1940, 84.) Anaerobe. From the female genital tract.

Vibrio napi Kalniņš. (Latvijas Ūniversitātes Raksti, Serija I, No. 11, 1930, 252.) Decomposes cellulose. From soil.

Vibrio n'dianka Hauduroy et al. (Thiroux, in Violle, Le Choléra, Masson édit., 1919; Hauduroy et al., Dict. d. Bact. Path., 1937, 546.) Isolated from a patient having a cholera-like disease.

Vibrio pericoma Kalniņš. (Latvijas Ūniversitātes Raksti, Serija I, No. 11, 1930, 256.) Decomposes cellulose. From soil.

Vibrio polymorphus Prévot. (Spirochete B, Repaci, Ann. Inst. Past., *26*, 1912, 544; *Vibrio pseudospirochaeta B*, Weinberg, Nativelle and Prévot, Les Microbes Anaérobies, 1936, 852; Prévot, Man. de Classif. des Bact. Anaér., Paris, 1940, 83.) Anaerobe. From the buccal cavity.

Vibrio polymorphus var. peritriche Prévot. (Spirochete C, Repaci, Ann. Inst. Past., *26*, 1912, 548; *Vibrio pseudospirochaeta C*, Weinberg, Nativelle and Prévot, Les Microbes Anaérobies, 1936, 854; Prévot, Man. de Classif. des Bact. Anaér., Paris, 1940, 84.) Anaerobe. From the buccal cavity.

Vibrio portuensis (Migula) Ford. (Der portuenser Vibrio, Jorge, Cent. f. Bakt., I Abt., *19*, 1896, 277; *Microspira portuensis* Migula, Syst. d. Bakt., *2*, 1900, 1007; Ford, Textb. of Bact., 1927, 353.) From water.

Vibrio prima Kalniņš. (Latvijas Ūniversitātes Raksti, Serija I, No. 11, 1930, 235.) Decomposes cellulose. From soil.

Vibrio pseudospirochaeta Prévot. (Spirochete A, Repaci, Ann. Inst. Past., *26*, 1912, 539; *Vibrio pseudospirochaeta A*, Weinberg, Nativelle and Prévot, Les Microbes Anaérobies, 1936, 849; Prévot, Man. de Classif. des Bact. Anaér., Paris, 1940, 83.) Anaerobe. From the buccal cavity.

Vibrio putridus Prévot. (Vibrion C, Repaci, Compt. rend. Soc. Biol. Paris,

* See *Nocardia lingualis* Chalmers and Christopherson.

1909, 630; Prévot, Man. de Classif. des Bact. Anaér., Paris, 1940, 83.) Anaerobe. From the buccal cavity.

Vibrio pyogenes (Doerr) Lehmann and Neumann. (Eiterspirillum, Mezinescu, Cent. f. Bakt., I Abt., Orig., *35*, 1904, 201; *Spirillum pyogenes* Doerr, Cent. f. Bakt., I Abt., Orig., *38*, 1905, 15; Lehmann and Neumann, Bakt. Diag., 4 Aufl., *2*, 1907, 493.) From pus in a case of pyelitis calculosa. Non-motile.

Vibrio ranicula Kalniņš. (Latvijas Ūniversitātes Raksti, Serija I, No. 11, 1930, 248.) Decomposes cellulose. From soil.

Vibrio rigensis Kalniņš. (Latvijas Ūniversitātes Raksti, Serija I, No. 11, 1930, 254.) Decomposes cellulose. From soil.

Vibrio rubicundus Gottron et al. (Gottron, Weaver and Sherago, Jour. Bact., *43*, 1942, 61.) From a trickling filter.

Vibrio septicus Kolle. (Kolle and Schümann in Kolle and Wassermann, Handb. d. path. Mikroörg., 2 Aufl., *4*, 1912, 101.) Identical with *Vibrio comma* culturally and morphologically. From a cholera-like disease.

Vibrio smithii (Migula) Ford. (Smith, Cent. f. Bakt., *10*, 1891, 177; *Microspira smithii* Migula, Syst. d. Bakt., *2*, 1900, 1006; Ford, Textb. of Bact., 1927, 340.) Possibly identical with *Microspira saprophiles* Migula, *Microspira weibelii* Migula, *Microspira cloaca* Chester and *Vibrio surati* Ford. From abscesses of large intestine of swine.

Vibrio spermatozoides Löffler. (Cent. f. Bakt., *7*, 1890, 638.) From kohlrabi infusions.

Vibrio sputigenus (Miller) Prévot. (*Spirillum sputigenum* Miller, Die Mikroorg. d. Mundhöhle, 2nd ed., 1892; Prévot, Man. de Classif. des Bact. Anaér., Paris, 1940, 85; not *Vibrio sputigenus* Bergey et al., Manual, 1st ed., 1923, 80.) Anaerobe. From the buccal cavity.

Vibrio sputigenus var. *minutissimus* Prévot. (Muhlens, Cent. f. Bakt., I Abt., *48*, 1909, 523; Prévot, Man. de Classif. des Bact. Anaér., Paris, 1940, 85.) Anaerobe. From the buccal cavity.

Vibrio sputorum Prévot. (Man. de Classif. des Bact. Anaér., Paris, 1940, 85.) Anaerobe. Isolated from a case of bronchitis.

Vibrio stationis Kalniņš. (Latvijas Ūniversitātes Raksti, Serija I, No. 11, 1930, 239.) Decomposes cellulose. From soil.

Vibrio stomatitis Prévot. (Vibrion A, Repaci, Compt. rend. Soc. Biol. Paris, 1909, 630; Prévot, Man. de Classif. des Bact. Anaér., Paris, 1940, 82.) Anaerobe. From the buccal cavity.

Vibrio subtilissimus (Migula) Ford. (Spirillum No. 1, Kutscher, Ztschr. f. Hyg., *20*, 1895, 46; *Spirillum tenerrimum* Lehmann and Neuman, Bakt. Diag., *2*, 1896, 346; *Spirillum subtilissimum* Migula, Syst. d. Bakt., *2*, 1900, 1020; Ford, Textb. of Bact., 1927, 341.) Regarded by Kutscher as being probably identical with the organism found by Smith (Cent. f. Bakt., *16*, 1894, 324) in swine dung. Resembles *Vibrio strictus*.

Vibrio suis Ford. (Vibrio No. 2, Kutscher, Ztschr. f. Hyg., *20*, 1895, 46; *Spirillum coprophilum* Migula, Syst. d. Bakt., *2*, 1900, 1019; not *Microspira coprophila* Migula, *loc. cit.*, 986; Ford, Textb. of Bact., 1927, 341.) From liquid manure.

Vibrio surati (Lamb and Paton) Ford. (*Spirillum surati* Lamb and Paton, Arch. Int. Med., *12*, 1913, 259; *Treponema surati* Brumpt, Nouveau Traité de Médecine, Paris, *4*, 1922, 514; Ford, Textb. of Bact., 1927, 337.) Isolated from a case of vegetative endocarditis. Closely resembles *Vibrio smithii* Ford, *Microspira weibelii* Migula, *Microspira saprophiles* Migula and *Microspira cloaca* Chester.

Vibrio synthetica Kalninš. (Latvijas Ūniversitātes Raksti, Serija I, No. 11, 1930, 245.) Decomposes cellulose. From soil.

Vibrio tenuis Veillon and Repaci.

(Ann. Inst. Past., *26*, 1912, 300.) Anaerobe. From the buccal cavity.

Vibrio terrigenus Günther. (Cent. f. Bakt., *16*, 1894, 746; *Spirillum terrigenum* Migula, Syst. d. Bakt., *2*, 1900, 1017; *Microspira terrigena* Chester, Man. Determ. Bact., 1901, 341.) Closely related to *Vibrio tonsillaris* Stephens and Smith. From soil.

Vibrio tonsillaris Stephens and Smith. (Cent. f. Bakt., *19*, 1896, 929; *Microspira tonsillaris* Migula, Syst. d. Bakt., *2*, 1900, 1009.) Closely related to *Vibrio terrigenus* Günther. From buccal cavity.

Vibrio toulonensis Hauduroy et al. (Vibrion, Defressine and Cazeneuve, in Violle, Le Choléra, Masson édit., 1919; Hauduroy et al., Dict. d. Bact. Path., 1937, 547.) From mussel beds in the bay of Toulon.

Vibrio xylitica Kalniņš. (Latvijas Ūniversitātes Raksti, Serija I, No. 11, 1930, 232.) Decomposes cellulose. From soil.

Genus II. Desulfovibrio *Kluyver and van Niel.**

(Cent. f. Bakt., II Abt., *94*, 1936, 369; *Sporovibrio* Starkey, Arch. f. Mikrobiol., *9*, 1938, 300.) From M. L. *desulfo*, an abbreviation of the poorly constructed word desulfofication, used to indicate reduction of sulfur compounds by bacteria; *vibrio*, vibrio.

Slightly curved rods of variable length, usually occurring singly but sometimes in short chains which have the appearance of spirilla. Swollen pleomorphic forms are common. Actively motile by means of a single polar flagellum. Strict anaerobes which reduce sulfates to hydrogen sulfide. Found in sea water, marine mud, fresh water, and soil.

The type species is *Desulfovibrio desulfuricans* (Beijerinck) Kluyver and van Niel.

1. **Desulfovibrio desulfuricans** (Beijerinck) Kluyver and van Niel. (*Bacterium hydrosulfureum ponticum* Zelinsky, Proc. Russ. Phys. and Chem. Soc., *25*, 1893, 298; *Spirillum desulfuricans* Beijerinck, Cent. f. Bakt., II Abt., *1*, 1895, 1: *Bacillus desulfuricans* Saltet, Cent. f. Bakt., II Abt., *6*, 1900, 648; *Microspira desulfuricans* Migula, Syst. d. Bakt., *2*, 1900, 1016; Kluyver and van Niel, Cent. f. Bakt., II Abt., *94*, 1936, 369; *Vibrio desulfuricans* Holland, Jour. Bact., *5*, 1920, 225; *Sporovibrio desulfuricans* Starkey, Koninkl. Nederland. Akad. v. Wetenschappen, Proc., *41*, 1938, 425; also in Arch. f. Microbiol., *9*, 1938, 268.) From M. L. present part. *desulfurico,* sulfur reducing.

Slightly curved rods, 0.5 to 1.0 by 1 to 5 microns, usually occurring singly but sometimes in pairs and short chains which cause them to look like spirilla. Swollen pleomorphic forms are common. Older cells appear black due to precipitated ferric sulfide. Actively motile, possessing a polar flagellum. Gram-negative. Stains readily with carbol fuchsin.

Grows best in freshwater media. Fails to develop in sea water upon initial isolation.

Produces opalescent turbidity in absence of oxygen in mineral media enriched with sulfate and peptone.

Media containing iron salts blackened. Bacteria found associated with precipitated ferrous sulfide.

Peptone-glucose agar colonies (in absence of air): Small, circular, slightly raised, dull, entire, soft in consistency.

Gelatin not liquefied.

Peptone, asparagine, glycine, alanine, aspartic acid, ethanol, propanol, butanol,

* Prepared by Dr. Claude E. ZoBell, Scripps Institution of Oceanography, La Jolla, California, Jan., 1943.

glycerol, glucose, lactate, succinate and malate known to be utilized as hydrogen donors.

Produces up to 500 ml. H_2S per liter.

Nitrites not produced from nitrates.

Reduces sulfate to hydrogen sulfide. Also reduces sulfites, sulfur, thiosulfates and hyposulfites.

Optimum pH 6 to 7.5, limits pH 5 to 9.

Optimum temperature 25 to 30° C. Maximum 35 to 40° C.

Anaerobic.

Habitat: Soil, sewage, water.

2. **Desulfovibrio aestuarii** (van Delden) *comb. nov.* (*Microspira aestuarii* van Delden, Cent. f. Bakt., II Abt., *11*, 1904, 81; *Vibrio desulfuricans* (halophilic strain) Baars, Over Sulfaatreductie door Bakterien, Diss. Delft, 1930, 164 pp.) From Latin, *aestuarium*, estuary.

Morphologically indistinguishable from *Desulfovibrio desulfuricans* described above, although it has a greater tendency to pleomorphism, and is slightly larger. Motile, possessing a polar flagellum. Gram-negative.

Grows preferentially in media prepared with sea water or 3 per cent salt mineral solution enriched with sulfate and peptone. According to Baars (*loc. cit.*) the marine species can be acclimatized to tolerate hypotonic salt solutions but Rittenberg (Studies on Marine Sulphate-Reducing Bacteria, Thesis, Univ. of Calif., 1941, 115 pp.) was unable to confirm this observation. Likewise Rittenberg was unable to acclimatize *D. aestuarii* to tolerate temperatures exceeding 45° C or to produce endospores.

Produces faint turbidity in absence of oxygen in sea water enriched with sulfate and peptone. Organisms most abundant in sediment.

Agar colonies: Small, circular, slightly raised, darker centers, entire, soft consistency.

Gelatin not liquefied.

Peptone, asparagine, glycine, alanine, glucose, fructose, ethanol, butanol, glycerol, acetate, lactate and malate known to be utilized in presence of sulfate.

Reduces sulfate to hydrogen sulfide. Also reduces sulfites, sulfur, thiosulfates and hyposulfites.

Produces up to 950 ml. H_2S per liter.

Nitrites not produced from nitrates.

Optimum temperature 25° to 30° C. Maximum 35° to 40° C.

Optimum pH 6 to 8, limits pH 5.5 to 8.5.

Anaerobic.

Habitat: Sea water, marine mud, brine and oil wells.

3. **Desulfovibrio rubentschickii** (Baars) *comb. nov.* (*Vibrio rubentschickii* Baars, Over Sulfaatreductie door Bakterien, Diss. Delft, 1930, 164 pp.) Named for L. Rubentschick.

Slightly curved rods, 0.5 to 1.0 by 1 to 5 microns, usually occurring singly, sometimes in pairs and short chains. Actively motile, possessing a polar flagellum. Gram-negative. Morphologically indistinguishable from *Desulfovibrio desulfuricans*.

Reduces sulfate to hydrogen sulfide. Also reduces sulfites, sulfur, thiosulfates and hyposulfites.

Culturally and physiologically like *D. desulfuricans* except that *D. rubentschickii* utilizes propionic acid, butyric acid, valeric acid, palmitic acid, stearic acid, galactose, sucrose, lactose and maltose.

Anaerobic.

Habitat: Soil and ditch water.

Appendix: The following species has also been regarded as belonging in this genus.

Vibrio thermodesulfuricans Elion. (Cent. f. Bakt., II Abt., *63*, 1924, 58); *Vibrio desulfuricans* (thermophilic strain) Baars, Over Sulfaatreductie door Bakterien, Diss. Delft, 1930, 164 pp.; *Sporovibrio desulfuricans* Starkey (Koninkl. Nederland. Akad. u. Wetenschappen, Proc., *41*, 1938, 425, also see Arch. f.

Microbiol., *9*, 1938, 268.) A thermophilic sulfate-reducing anaerobe which grows at 30 to 65°C. and which, according to Starkey, produces endospores. Elion described *Vibrio thermodesulfuricans* (Cent. f. Bakt., II Abt., *63*, 1924, 58) which grows at temperatures no lower than 30 to 40°C. and has an optimum of 55°C. Morphologically it is much like *Desulfovibrio desulfuricans* and *D. aestuarii* although the thermophilic form is shorter, more rod-like, less motile and more pleomorphic. According to Baars (*loc. cit.*), *Vibrio thermodesulfuricans* Elion can be acclimatized to grow at lower temperatures and it is found abundantly in environments where the temperature has never been as high as 30°C. This observation is confirmed by Starkey (Arch. f. Microbiol., *9*, 1938, 268) who found further that the thermophilic form found in nature or developed by acclimatization to higher temperatures produces endospores. However, spore-formation appears to be the exception rather than the rule. The pleomorphic, peritrichous, sporogenous, sulfate-reducer is more rod-like than the asporogenous cultures and many cells of the sporogenous cultures are Gram-positive whereas asporogenous cultures of *Desulfovibrio desulfuricans* are Gram-negative, all of which leaves a question whether the sporogenous sulfate-reducer is a *Bacillus* or a *Desulfovibrio*. Rittenberg (Studies on Marine Sulfate-reducing Bacteria, Thesis, Univ. Calif., 1941, 115 pp.) was unable to adapt the marine sulfate reducer to grow at low salinities or at high temperatures, nor could it be induced to form spores.

Desulfovibrio halohydrocarbonoclasticus Zobell (U. S. Patent No. 2,413,278; Science News Letter, Jan. 11, 1947.) From oil bearing rocks.

Genus III. **Cellvibrio** *Winogradsky.**

(Ann. Inst. Pasteur, *43*, 1929, 577.) From M. L. cell, an abbreviation for cellulose; *vibrio*, vibrio.

Long slender rods, slightly curved, with rounded ends, show deeply staining granules which appear to be concerned in reproduction. Monotrichous. Most species produce a yellow or brown pigment with cellulose. Oxidize cellulose, forming oxycellulose. Growth on ordinary culture media is feeble. Found in soil.

The type species is *Cellvibrio ochraceus* Winogradsky.

Key to the species of genus **Cellvibrio.**

I. No growth on glucose or starch agar.
  A. Ochre-yellow pigment produced on filter paper.
    1. *Cellvibrio ochraceus.*

II. Growth on glucose and starch agar.
  A. Poor growth on starch agar.
    1. Cream-colored pigment which becomes brown with age is produced on filter paper.
      2. *Cellvibrio flavescens.*
  B. Abundant growth on starch agar.
    1. Scanty growth on glucose agar.
      a. Intense yellow pigment produced on filter paper.
        3. *Cellvibrio fulvus.*
    2. Abundant growth on glucose agar.
      a. No pigment produced on filter paper.
        4. *Cellvibrio vulgaris.*

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* Revised by Prof. Robert S. Breed, New York State Experiment Station, Geneva, New York, Sept., 1937; no change. July, 1943.

1. **Cellvibrio ochraceus** Winogradsky. (Ann. Inst. Pasteur, *43*, 1929, 549, 601.) From Greek, *ōchra*, yellow ochre; M. L. like ochre, yellow.

Plump, curved rods with rounded ends, 2.0 to 4.0 microns long, rarely occurring as spirals. Chromatic granule frequently found in center. Motile with a single flagellum. Gram-negative.

Produces diffuse, light ochre-colored, mucilaginous colonies on cellulose silica gel medium.

No action or growth on plain agar. No growth on peptone, glucose, starch or tragacanth gum agar.

Filter paper streaks: Entire paper colored ochre-yellow in 48 hrs.

Aerobic, facultative.

Optimum temperature 20°C.

Distinctive character: Rapid ochre-colored growth.

Habitat: Soil. Disintegrates vegetable fibers.

2. **Cellvibrio flavescens** Winogradsky. (Ann. Inst. Pasteur, *43*, 1929, 608.) From Latin, part. adj. of *flavesco*, to turn yellow or golden.

Plump, curved rods, flexuous, with rounded ends, 0.5 by 2.5 to 5.0 microns. Shows metachromatic granules. Motile with a single flagellum. Gram-negative.

Produces diffuse, cream-colored growth becoming brownish; mucilaginous colonies on cellulose silica gel medium.

Good growth on peptone agar. Colonies 1 mm in 4 days. Grows poorly on glucose, starch and gum agars.

Filter paper streaks: Almost as rapid in growth as *Cellvibrio ochraceus* and colors entire paper in 2 to 3 days.

Aerobic, facultative.

Optimum temperature 20°C.

Distinctive characters: Smaller, less curved rods that grow on a greater variety of media than *Cellvibrio ochraceus*, but do not attack cellulose as readily.

Source: Isolated from a pile of old damp sawdust.

Habitat: Soil. Disintegrates vegetable fibers.

3. **Cellvibrio fulvus** Stapp and Bortels. (Culture Y, Dubos, Jour. Bact., *15*, 1928, 230; Stapp and Bortels, Cent. f. Bakt., II Abt., *90*, 1934, 42.) From Latin, *fulvus*, reddish yellow.

Slightly curved rods: 0.3 to 0.4 by 1.5 to 3.0 microns. Show involution forms. Motile by means of a single polar flagellum. Gram-negative.

Cellulose is decomposed. Grows on filter paper with an intense egg-yellow color which in older cultures may deepen to rust brown.

Glucose agar: Very scanty growth.

Sucrose agar: Very slight growth.

Maltose agar: Abundant yellow growth.

Lactose agar: Fairly abundant yellow growth.

Starch agar: Very abundant, bright yellow growth which later turns brown.

Nutrient broth: No growth.

Temperature relations: Optimum 25° to 30°C. Minimum 5°C. Maximum 32° to 35°C. No growth at 37°C. Thermal death point 39° to 40°C.

Aerobic.

Source: Isolated from forest soil in Germany and from soil in the United States.

Habitat: Widely distributed in soils.

4. **Cellvibrio vulgaris** Stapp and Bortels. (Culture Co, Dubos, Jour. Bact., *15*, 1928, 230; Stapp and Bortels, Cent. f. Bakt., II Abt., *90*, 1934, 44.) From Latin, *vulgaris*, common.

Curved rods: 0.3 by 2.9 to 4.0 microns. Shows involution forms. Motile by means of a single polar flagellum. Gram-negative.

Cellulose is decomposed. Grows on filter paper without the formation of pigment.

Glucose agar: Abundant growth. No pigment.

Sucrose agar: Abundant slightly yellow growth.

Maltose agar: Abundant yellowish growth.

Lactose agar: Very heavy growth.

Starch agar: Very abundant yellowish growth.

Nutrient broth: No growth.

Temperature relations: Optimum 25° to 30°C. Minimum 5°C. Maximum 32° to 35°C. No growth at 37°C. Thermal death point 44° to 45°C.

Aerobic.

Source: Isolated from forest soil in Germany and from soils in the United States.

Habitat: Widely distributed in soils.

Genus IV. **Cellfalcicula** *Winogradsky.**

(Ann. Inst. Pasteur, *43*, 1929, 616.) From M. L. cell, an abbreviation for cellulose; Latin dim., *falcicula*, a small sickle.

Short rods or spindles, not exceeding 2.0 microns in length, with pointed ends, containing metachromatic granules. Old cultures show coccoid forms. Monotrichous. Oxidize cellulose, forming oxycellulose. Growth on ordinary culture media is feeble. Soil bacteria.

The type species is *Cellfalcicula viridis* Winogradsky.

1. **Cellfalcicula viridis** Winogradsky. (Ann. Inst. Pasteur, *43*, 1929, 616.) From Latin, *viridis*, green.

Plump, small spindles, 0.7 by 2.0 microns, with rounded ends. Motile with a single flagellum. Gram-negative.

Produces diffuse green, mucilaginous colonies on cellulose silica gel medium.

Filter paper streaks: Rapid spreading growth colored green in 3 days at 30°C.

Hydrocellulose agar: Growth rapid, green; minute yellowish-green, mucous colonies on streaking.

No growth on peptone, glucose, starch or gum agar.

Aerobic, facultative.

Optimum temperature 20°C.

Habitat: Soil.

2. **Cellfalcicula mucosa** Winogradsky. (Ann. Inst. Pasteur, *43*, 1929, 621.) From Latin, *mucosus*, mucous.

Plump, curved spindles, with slightly pointed ends. Motile with a single polar flagellum. Contain a single chromatic granule. Gram-negative.

Produces diffuse, cream-colored, mucilaginous colonies on cellulose silica gel medium.

Hydrocellulose agar: Abundant grayish growth.

No growth on peptone, glucose, starch or gum agar.

Aerobic, facultative.

Optimum temperature 20°C.

Habitat: Soil.

3. **Cellfalcicula fusca** Winogradsky. (Ann. Inst. Pasteur, *43*, 1929, 622.) From Latin, *fuscus*, dark, tawny.

Plump, curved spindles, 0.5 by 1.2 to 2.5 microns, with slightly pointed ends and a central chromatic granule. Motile with a single polar flagellum. Gram-negative.

Produces diffuse, brownish, slightly marbled or veined colonies on cellulose silica gel medium.

Filter paper streak: Paper becomes a partially transparent, dry, non-mucilaginous pellicle adherent to gel.

Aerobic, facultative.

Optimum temperature 20°C.

Source: Isolated from a pile of old damp sawdust.

Habitat: Probably rotting wood.

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* Revised by Prof. Robert S. Breed, New York State Experiment Station, Geneva, New York, Sept., 1937; no change, July, 1943.

Genus V. **Thiospira** *Vislouch.**

(Jour. de Microbiologie, *1*, 1914, 50; *Sulfospirillum* Kluyver and van Niel, Cent. f. Bakt., II Abt., *94*, 1936, 396.) From Greek, *theion*, sulfur; *speira*, coil.

Colorless, motile, slightly bent rods, somewhat pointed at the ends, with granules of sulfur within the cells and a small number of flagella at the ends.

The type species is *Thiospira winogradskyi* (Omelianski) Vislouch.

1. **Thiospira winogradskyi** (Omelianski) Vislouch. (*Thiospirillum winogradskyi* Omelianski, Cent. f. Bakt., II Abt., *14*, 1905, 769; *Thiospirillum granulatum* Molisch, Cent. f. Bakt., II Abt., *33*, 1912, 55; Vislouch, Jour. de Microbiologie (Russian), *1*, 1914, 50; *Sulfospirillum winogradskyi* Kluyver and van Niel, Cent. f. Bakt., II Abt., *94*, 1936, 397.) Named for Winogradsky, the Russian bacteriologist.

Large, sulfur spirilla, somewhat pointed at the ends, 2 to 2.5 microns thick, to 50 microns long. Numerous granules of sulfur. Very motile, with one to two polar flagella.

Habitat: Curative mud.

2. **Thiospira bipunctata** (Molisch) Vislouch. (*Spirillum bipunctatum* Molisch, Cent. f. Bakt., II Abt., *33*, 1912, 55; Vislouch, Jour. de Microbiologie (Russian), *1*, 1914, 50.) From Latin, *bi*, two; *punctum*, points.

Small, slightly bent sulfur spirilla, markedly pointed at the ends, 6.6 by 14 microns long, 1.7 to 2.4 microns wide (in the center of the cell). Both ends are filled more or less with large volutin (metachromatic) granules. Several minute granules of sulfur are present in the clear center and sometimes at the ends. Old cells possess one flagellum at each end; young cells have a flagellum at one end.

Habitat: Sea and salt waters.

Genus VI. **Spirillum** *Ehrenberg.*†

(Ehrenberg, Abhandlungen d. Berl. Akad., 1830, 38; *Spirosoma* Migula, Arb. bakt. Inst. Karlsruhe, *1*, 1894, 237; *Dicrospirillum* Enderlein, Sitzber. Gesell. naturf. Freunde, Berlin, 1917, 313.) From Greek, *speira*, a spire or coil.

Cells form either long screws or portions of a turn. Volutin granules are usually present. Usually motile by means of a tuft of polar flagella (5–20) which may occur at one or both ends of the cells. Aerobic, growing well on ordinary culture media, except for one saprophyte and the pathogenic species. These have not yet been cultivated. Usually found in fresh and salt water containing organic matter.

The type species is *Spirillum undula* (Müller) Ehrenberg.

Key to the species of genus **Spirillum.**

I. One micron or less in diameter.
  1. Volutin granules present.
    a. Slow to rapid liquefaction of gelatin.
      b. Grayish to brown growth on potato.
        1. *Spirillum undula.*

---

* Prepared by Prof. D. H. Bergey, Philadelphia, Penn., October, 1922.

† Revised by Prof. D. H. Bergey, Philadelphia, Pennsylvania, April, 1937; further revision by Prof. Robert S. Breed, New York State Experiment Station, Geneva, New York, June, 1943, based on Monograph by Giesberger, Inaug. Diss., Utrecht, Nov. 30, 1936.

bb. Light yellowish-orange growth on potato.

2. *Spirillum serpens.*

aa. No liquefaction of gelatin. Of small size (0.5 micron in diameter).

b. Colonies on agar white becoming brownish black and slightly wrinkled.

3. *Spirillum itersonii.*

bb. Colonies on agar white and smooth.

4. *Spirillum tenue.*

2. No volutin granules observed.

b. Single flagellum.

5. *Spirillum virginianum.*

bb. Tuft of flagella.

6. *Spirillum minus.*

II. Over one micron in diameter.

1. Grows poorly on peptone agar and potato.

7. *Spirillum kutscheri.*

2. Not positively known to have been cultivated on artificial media. Very evident volutin granules.

8. *Spirillum volutans.*

3. Cells more or less deformed by fat drops.

9. *Spirillum lipoferum.*

1. **Spirillum undula** (Müller) Ehrenberg. (*Vibrio undula* Müller, Animalcula infusoria et marina, 1786; Ehrenberg, Infusionstierchen, 1838; *Spirillum undula minor* Kutscher, Cent. f. Bakt., I Abt., *18*, 1895, 614.) From Latin, *undulatus*, wave-like.

Stout threads, 0.9 micron in diameter, with one-half to three turns. The wave lengths are 6 microns. Width of spiral, 3.0 microns. Tufts of three to nine flagella at each pole. Volutin granules present. Gram-negative.

Gelatin colonies: The surface colonies are circular, granular, greenish-yellow, entire.

Gelatin stab: Thick, white, rugose surface growth. Very slow liquefaction.

Agar colonies: Grayish-white, smooth.

Broth: Turbid.

Potato: Grayish-brown growth.

Indole not formed.

Catalase positive.

Nitrites not produced from nitrates.

Aerobic, facultative.

Optimum temperature 25°C.

Cohn (Beitrage z. Biol. d. Pflanzen, *1*, Heft 2, 1875, 132) reports that he could not distinguish this organism from *Vibrio prolifer* Ehrenberg.

Habitat: Putrid and stagnant water.

2. **Spirillum serpens** (Müller) Winter. (*Vibrio serpens* Müller, Animalcula infusoria et marina, 1786, 43; Winter, in Rabenhorst's Kryptogamen-Flora, *1*, Die Pilze, 1884, 63.) From Latin, *serpens*, serpent.

Long, curved rods with two to three wave-like undulations, 0.8 to 1.0 micron in diameter; wave length, 8 to 9 microns. Width of spiral 1.5 to 1.8 microns. Volutin granules in cytoplasm. Motile, possessing tufts of flagella at both poles. Gram-negative.

Gelatin colonies: Yellowish to brownish, granular, entire.

Gelatin stab: Yellowish surface growth. Slow liquefaction.

Agar colonies: Heavy cream-colored growth.

Agar slant: Grayish, with yellowish center, granular, entire.

Broth: Turbid.

Litmus milk: Unchanged.

Potato: Clear orange-yellow growth

Indole not formed.

Catalase positive.
Nitrites not produced from nitrates.
Aerobic, facultative.
Optimum temperature 35°C.
Habitat: Stagnant water.

3. **Spirillum itersonii** Giesberger. (Inaug. Diss., Utrecht, 1936, 46 and 57.) Named for van Iterson, the Dutch bacteriologist.

The smallest of the spirilla isolated from water. First observed by van Iterson (Proc. Kon. Akad. v. Wetensch. Amsterdam, *5*, 1902, 685).

Small spirals, 0.5 micron in diameter. Wave length, 3 to 3.5 microns. Spiral width, 1 to 1.5 microns. Motile with bipolar tufts of flagella. Gram-negative.

Grows readily on peptone agar. White colonies becoming brownish black, and slightly wrinkled.

Gelatin stab: No liquefaction.

Brownish-orange growth on potato.

Volutin granules may be present.

Catalase is produced.

Acid from glucose, fructose, ethyl alcohol, n-propyl alcohol, n-butyl alcohol, and glycerol. Utilizes acetic, propionic, n-butyric, tartaric, fumaric, lactic, citric, and succinic acids.

Grows well in peptone broth. Also utilizes ammonia compounds.

Anaerobic growth in the presence of nitrates when organic or ammonia nitrogen is also available.

Optimum temperature: 30°C.

Source: Isolated from water.

Habitat: Water.

4. **Spirillum tenue** Ehrenberg. (Infusionstierchen, 1838; see Bonhoff, Arch. f. Hyg., *26*, 1896, 162.) From Latin, *tenuis*, thin.

Slender spirals. Diameter 0.7 micron. Wave lengths 4.5 to 5.0 microns. Width of spiral 1.5 to 1.8 microns.

Actively motile in peptone water with tufts of flagella at each pole. Volutin granules present. Gram-negative.

Agar colonies: White, smooth.

Peptone agar slant: Heavy growth.

Gelatin stab: No liquefaction.

Catalase positive.

Potato: Light brown growth.

Acid from glucose and fructose. Slight acid from several other sugars and glycerols. Utilizes salts of acetic, propionic, n-butyric, tartaric, lactic, citric, malic, and succinic acids.

Ammonia compounds are used as a source of nitrogen.

Optimum temperature, 30°C.

Source: Found in putrefying vegetable matter.

Habitat: Putrefying materials.

5. **Spirillum virginianum** Dimitroff. (Jour. of Bact., *12*, 1926, 19.) From M. L. genitive of Virginia.

Spirals consisting of ½ to 3 complete turns in young cultures, older cultures showing 7 turns. 0.6 to 0.9 by 3 to 11 microns. Motile with a single polar flagellum on one or both ends. Gram-negative.

Gelatin colonies: Entire, convex, circular, moist, colorless.

Gelatin stab: Growth along entire stab. No liquefaction. (Dimitroff, *loc. cit.*) Active liquefaction. (Giesberger, Inaug. Diss., Utrecht, 1936, 65.)

Agar colonies: Dew drop, convex, entire, moist, colorless.

Agar slant: Dew drop, isolated colonies.

Broth: Cloudy, no flocculation.

Uschinsky's protein-free medium: Abundant growth.

Litmus milk: No growth.

Loeffler's blood serum: Convex, isolated dew drop colonies. No liquefaction.

Lead acetate agar: No H_2S.

Voges-Proskauer and methyl red negative.

No volutin granules observed (Giesberger, *loc. cit.*, p. 60).

Potato: No growth.

Indole not formed.

Nitrites not produced from nitrates.

No acid or gas from carbohydrates.

(Dimitroff, *loc. cit.*). Utilizes lactates and citrates (Giesberger, *loc. cit.*).

Aerobic, facultative.

Optimum temperature 35°C.

Source: Isolated from mud on an oyster shell.

Habitat: Probably muddy bottom of brackish water.

6. **Spirillum minus** Carter. (Carter, Sci. Mem. Med. Officers Army India, *3*, 1887, 45; *Spirillum minor* Carter, *ibid.*; *Spirochaeta laverani* Breinl and Kinghorn, Mem. Liverpool Sch. Trop. Med., *21*, 1906, 55; *Spirochaeta muris* Wenyon, Jour. Hyg., *6*, 1906, 580; *Spirochaeta muris* var. *virginiana* MacNeal, Proc. Soc. Exper. Biol. and Med., *4*, 1907, 125; *Spirochaeta muris* var. *galatziana* Mezincescu, Compt. rend. Soc. Biol. Paris, *66*, 1909, 58; *Treponema muris* Moore, Principles of Microbiology, 1912, 414; *Spirochaeta morsus muris* Futaki, Takaki, Taniguchi and Osumi, Jour. Exp. Med., *25*, 1917, 33; *Spirochaeta petit* Row, Ind. Jour. Med. Res., *5*, 1917, 386; *Spironema muris* Noguchi, Jour. Exp. Med., *27*, 1918, 584; *Spirochaeta japonica* Dujarric de la Rivière, Ann. de Méd., *5*, 1918, 184; *Spirochaeta morsusmuris* Castellani and Chalmers, Man. Trop. Med., 3rd ed., 1919, 447; *Spiroschaudinnia morsusmuris* Castellani and Chalmers, *ibid.*; *Spirochaeta sodoku* Troisier, 1920, according to Pettit, Contribution à l'Étude des Spirochétidés, Vanves, II, 1928, 231; *Treponema japonicum* Brumpt, Nouveau Traité de Médecine, Paris, *4*, 1922, 505; *Treponema morsus muris* Brumpt, *ibid.*, 506; *Treponema minor* Brumpt, *ibid.*, 507; *Treponema laverani* Brumpt, *ibid.*, 507; *Treponema sodoku* Brumpt, *ibid.*, 514; *Spirochaeta pettiti* Row, Jour. Trop. Med. and Hyg., *25*, 1922, 364; *Treponemella muris* San Giorgi, Pathologica rivista, *14*, 1922, 461; *Borrelia muris* Bergey et al., Manual, 2nd ed., 1925, 435; *Spirillum minus* var. *morsus muris* Ruys, Cent. f. Bakt., I Abt., Orig., *103*, 1927, 270; *Spirillum minus* var. *muris* Ruys, *ibid.*; *Spironema minor* Ford, Textb. of Bact., 1927, 962; *Spironema laverani* Ford, *ibid.*, 963; *Spironema muris* var. *virginiana* Ford, *ibid.*, 963; *Spirella morsusmuris* Noguchi, in Jordan and Falk, Newer Knowledge Bact. and Immun., 1928, 497; *Spirella muris* Noguchi, *ibid.*) From Latin, *minus*, less.

Description taken from Adachi, Jour. Exp. Med., *33*, 1921, 647 and Giesberger, Inaug. Diss., Delft, 1936, 67.

Short thick cells: 0.5 by 3.0 microns, having 2 or 3 windings which are thick, regular and spiral. Actively motile by means of bipolar tufts of flagella. Gram-negative.

Has not been cultivated on artificial media.

Aerobic, facultative.

Pathogenic for man, monkeys, rats, mice and guinea pigs.

This species is regarded by some as a spirochaete. Because of its habitat and wide distribution it has been described under many different names. It is possible that some of these names indicate varieties or even separate species. See Beeson (Jour. Amer. Med. Assoc., *123*, 1943, 332) for important literature.

Source: Found in the blood of rats and mice.

Habitat: The cause of rat-bite fever. Widely distributed.

7. **Spirillum kutscheri** Migula. (*Spirillum undula majus* Kutscher, Cent. f. Bakt., I Abt., *18*, 1895, 614; Migula, Syst. d. Bakt., *2*, 1900, 1024.) Named for Kutscher, the German bacteriologist who first isolated the organism.

Stout threads, 1.5 microns in diameter. Wave lengths 10.5 to 12.5 microns. Width of spiral, 3 to 4.5 microns. May lose their spiral form on continued cultivation. Motile with tufts of flagella at the poles. Gram-negative.

Gelatin colonies: Transparent, round, surface colonies. Deep colonies, dark brown.

Gelatin stab: Slow liquefaction.

Agar colonies grow poorly, granular. Deep colonies yellowish-green to dark brown.

Agar slant: Delicate, transparent growth.

Potato: Limited growth.

Volutin present.

Catalase positive.

Utilizes malic and succinic acids.

Grows well on peptone broth. Also utilizes ammonia compounds.

Optimum temperature, 22° to 27°C.

Source: Isolated from putrid materials and liquid manure.

Habitat: Putrefying liquids.

8. **Spirillum volutans** Ehrenberg. (Prototype, *Vibrio spirillum* Müller, Animalcula infusoria, 1786; Ehrenberg, Die Infusionstierchen als Volkommene Organismen, 1838.) From M. L. volutin.

Spirals 1.5 microns in diameter. Wave length, 13 to 15 microns, width of spiral, 4 to 5 microns. The largest of the spirilla. Slightly attenuated ends. Motile, possessing a tuft of ten to fifteen flagella at each pole. Dark granules of volutin in the cytoplasm. Gram-negative.

Migula (Syst. d. Bakt., *2*, 1900, 1025) reports that this species has not been cultivated on artificial media, and that the cultures so described by Kutscher (Ztschr. f. Hyg., *20*, 1895, 58) are of a different species which Migula names *Spirillum giganteum*. Vahle (Cent. f. Bakt., II Abt., *25*, 1910, 237) later describes the cultural characters of an organism which he regards as identical with Kutscher's organism. Giesberger (Inaug. Diss., Delft, 1936, 65) saw what he felt was the true *Spirillum volutans* but could not cultivate it.

Optimum temperature 35°C.

Habitat: Stagnant water.

9. **Spirillum lipoferum** Beijerinck. (*Azotobacter spirillum* Beijerinck, Kon. Akad. Wetensch. Amsterdam, *30*, 1923, 431 quoted from Giesberger, Inaug. Diss., Delft, 1936, 24; *Spirillum lipoferum* Beijerinck, Cent. f. Bakt., II Abt., *63*, 1925, 353; *Chromatium lipoferum* Bergey et al., Manual, 3rd ed., 1930, 531.) From Greek, *lipos*, fat; Latin, *fero*, to bear.

Curved cells with one-half to one spiral turn, containing minute fat droplets. These may deform the cells. Motile with lophotrichous flagella. Gram-negative.

Calcium malate agar colonies: Circular, small, transparent, dry. The malate is oxidized to calcium carbonate. Cells contain fat drops.

Peptone agar colonies: More abundant development. Cells lack fat drops and are typically spirillum in form.

Glucose peptone broth: Cells actively motile with large fat drops.

Fixes atmospheric nitrogen in partially pure cultures, i.e., free from *Azotobacter* and *Clostridium* (Beijerinck, *loc. cit.*). Schröder (Cent. f. Bakt., II Abt., *85*, 1932, 17) failed to find fixation of nitrogen when she used cultures derived from a single cell.

Aerobic.

Optimum temperature 22°C.

Beijerinck regards this as a transitional form between *Spirillum* and *Azotobacter*. Giesberger (*loc. cit.*, p. 64–65) thinks it a *Vibrio*.

Habitat: Garden soil.

Appendix:* The following additional species have been mentioned in the literature. Many are inadequately described. Some may not belong here.

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* Prepared by Mr. Wm. C. Haynes, New York State Experiment Station, Geneva, New York, Jan., 1939; Revised by Capt. Wm. C. Haynes, Sn. C., Fort Bliss, Texas July, 1943.

Spirella canis Duboscq and Lebailly. (Compt. rend. Acad. Sci. Paris, *154*, 1912, 835.) From the stomach of a dog.

Spirillum amyliferum Van Tieghem. (Bull. Soc. botan. de France, *26*, 1879, 65.) Said to produce spores. Ford (Textb. of Bact., 1927, 364) thinks this organism was probably a spirochaete because of its mode of division. Found in frog spawn fungus of sugar factories.

Spirillum attenuatum Warming. (Om nogle ved Danmarks Kyster levende Bakterier. Kjobenhavn, 1876; *Spirosoma attenuatum* Migula, Syst. d. Bakt., *2*, 1900, 959.) Ford (*loc. cit.*, 363) states that this incompletely described organism would now be regarded either as a spirillum or as a spirochaete. From sea coast of Denmark.

Spirillum cardiopyrogenes Sardjito. (Geneesk. Tijdschr. voor Ned.-Indie, *72*, 1932, 1359; *ibid.*, *73*, 1933, 822.) From blood of a patient with pericarditis.

Spirillum colossus Errera. (Rec. trav. bot. Bruxelle, *5*, 1902; Abst. in Cent. f. Bakt., II Abt., *9*, 1902, 608.) A giant form isolated from brackish sea water. Probably the same as *Spirillum volutans* Ehrenberg.

Spirillum concentricum Kitasato. (Cent. f. Bakt., *3*, 1888, 73.) Found in putrefying blood.

Spirillum crassum Veillon and Repaci. (Ann. Inst. Past., *26*, 1912, 300.) Described as having peritrichous flagella. From lung lesions in human tuberculosis.

Spirillum endoparagogicum Sorokin. (Cent. f. Bakt., *1*, 1887, 465.) Described as producing spores in old cultures. From rain water in bark of poplar tree.

Spirillum giganteum Migula. (*Spirillum volutans* Kutscher, Ztschr. f. Hyg., *20*, 1895, 58; Migula, Syst. d. Bakt., *2*, 1900, 1025.) From putrefying liquids.

Spirillum hachaizae Kowalski. (Cent. f. Bakt., *16*, 1894, 324; *Spirillum hachaizicum* Kowalski, *ibid.*, 324; *Spirochaeta hachaizae* Castellani and Chalmers, Man. Trop. Med., 1st ed., 1910, 316; *Treponema hachaizae* Brumpt, Nouveau Traité de Médecine, Paris, *4*, 1922, 495.) Found in feces of cholera patients and also of healthy individuals.

Spirillum kolkwitzii Vislouch. (Jour. de Microbiol. (Russian), *1*, 1914, 50.)

Spirillum leucomclaenum Perty. (Zur Kenntniss kleinster Lebensformen. Berne, 1852. Also see Koch, Mitt. Kais. Gesundheitsamte, *1*, 1881, 48.) From stagnant water.

Spirillum monospora Dobell. (Quart. Jour. Micr. Sci., *52*, 1908, 121.) Described as producing spores. From large intestine of frogs and toads.

Spirillum nigrum Rist. (Thèse méd., Paris, 1898; see Cent. f. Bakt., I Abt., *30*, 1901, 299.) Strict anaerobe from pus.

Spirillum ostreae Noguchi. (Jour. Exp. Med., *34*, 1921, 295.) From oysters.

Spirillum periplaneticum Kunstler and Gineste. (Compt. rend. Soc. Biol. Paris, *61*, 1906, 135.) From the intestine of the cockroach, *Periplaneta americana*.

Spirillum pyogenes Mezincescu. (Cent. f. Bakt., I Abt., Orig., *35*, 1904, 201; *Spirochaeta pyogenes* Blanchard, Semaine Méd., *26*, 1906, 1; *Treponema pyogenes* Brumpt, Nouveau Traité de Médecine, Paris, *4*, 1922, 511.) From a case of pyelitis calculosa.

Spirillum rappini De Toni and Trevisan. (Spirochaete, Rappin, Contr. à l'Étude d. Bactér. de la Bouche à l'État normal, 1881, 68; De Toni and Trevisan, in Saccardo, Sylloge Fungorum, *8*, 1889, 1009.) From the stomach of a dog.

Spirillum recti physeteris Beauregard. (Compt. rend. Acad. Sci. Paris, *125*, 1897, 255.) From ambergris.

Spirillum rugula (Müller) Winter. (*Vibrio rugula* Müller, Animalcula infusoria, 1786; Cohn, Beitrage z. Biol. d. Pflanz., *1*, Heft 2, 1872, 178; Bonhoff, Arch. f. Hyg., *26*, 1896, 162; Winter, Die Pilze, in Rabenhorst's Kryptogamen-Flora, 1884.) Prazmowski found spores, but it is not certain his cultures were pure. Bonhoff also observed spores, but

concluded that they were due to contaminating organisms (Ford, Textb. of Bact., 1927, 360). From water.

Spirillum sporiferum Migula. (Syst. d. Bakt., *2*, 1900, 1028.) Produces spores. The spirals in which the spore formation is beginning are like *Spirillum leucomelaenum* Perty (Ford, *loc. cit.*, 336). Giesberger (*loc. cit.*, p. 60) places this and other so-called spore-forming spirilla in *Sporospirillum* Orla-Jensen (Cent. f. Bakt., II Abt., *22*, 1909, 340). From a bean infusion.

Spirillum sputigenum Miller. (Die Mikroörganismen der Mundhöhle. Leipzig, 1892; Deutsche med. Wchnschr., *32*, 1906, 1 and 348.) Hoffman and Prowazek (Cent. f. Bakt., I Abt., Orig., *41*, 1906, 741) claim that *Spirillum sputigenum* has peritrichous flagella. Giesberger (*loc. cit.*, 63) places this in *Selenomonas* Prowazek (Cent. f. Bakt., I Abt., Orig., *70*, 1913, 36). Muhlens (Cent. f. Bakt., I Abt., Orig., *48*, 1909, 525) reports 1 to 3 flagella, the majority of the organisms having apparently a single thick flagellum (a bunch of flagella) on the concave side (Ford, *loc. cit.*, 367). Anaerobic. From the buccal cavity.

Spirillum stomachi Lehmann and Neumann. (*Spirillum* Form α, β, γ, δ Salomon, Cent. f. Bakt., I Abt., *19*, 1896, 433; Lehmann and Neumann, Bakt. Diag., 2 Aufl., *2*, 1899, 362.) Found in stomach of dog, cat and rat.

Paraspirillum vejdovskii Dobell. (Arch. f. Protistenk., *24*, 1911, 97.) Found only once in fresh water containing *Oscillatoria*. Flagellate flexible spiral cells described as possessing a nucleus. This may be a protozoan.

Spirobacillus gigas Certes. (Bull. Soc. Zool. France, *14*, 1889, 322; abst. in Ann. de Microgr., *2*, 1889–1890, 137.) From water.

Vibriothrix tonsillaris Tunnicliff and Jackson. (Organism from Actinomyces-like granules, Tunnicliff, Jour. Inf. Dis., *38*, 1926, 366; Tunnicliff and Jackson, *ibid.*, *46*, 1930, 12.) From tonsillar granules. May be identical with *Leptothrix asteroide* Mendel and as a Gram-negative, anaerobe may belong in *Bacteroides* according to Rosebury (Bact. Rev., *8*, 1944, 202).

Vibriothrix zeylanica (Castellani) Castellani. (*Spirillum zeylanicum* Castellani Jour. Ceylon Branch Brit. Med. Assoc., 7, 1910, 5 and Philipp. Jour. Sci., *5*, No. 2, Sect. B., Medical Sciences, July, 1910; *Vibrio zeylanicus* Castellani, 1913, *Bacillus zeylanicus* Castellani, 1913 and *Vibriothrix zeylanica* Castellani, 1917, quoted from Castellani and Chalmers, Man. Trop. Med., 3rd ed., 1919, 1069; *Spirobacillus zeylanicus* Castellani, Spagnuolo and Russo, Bull. Soc. Path. Exot., *11*, 1918, 271.) Motile. Gram-negative. From cases of dysenteric enteritis in Ceylon. This is the type species of the genus *Vibriothrix* Castellani (see Castellani and Chalmers, *loc. cit.*, 1068).

FAMILY III. AZOTOBACTERIACEAE BERGEY, BREED AND MURRAY.*

(Preprint, Manual, 5th ed., October, 1938, v and 71.)

Cells without endospores. Relatively large rods or even cocci, sometimes almost yeast-like in appearance. The type of flagellation in this genus has been definitely established as peritrichous. Gram-negative. Obligate aerobes, usually growing in a film on the surface of the culture medium. Capable of fixing atmospheric nitrogen when provided with carbohydrate or other energy source. Grow best on media deficient in nitrogen. Soil and water bacteria.

There is a single genus.

Genus I. **Azotobacter** *Beijerinck.*

(Beijerinck, Cent. f. Bakt., II Abt., *7*, 1901, 567; *Azotomonas* Orla-Jensen, Cent. f. Bakt., II Abt., *24*, 1909, 444.)

The definition is identical with that of the family. From Gr. *azous*, not living. French, *azote*, nitrogen; Gr. *baktron*, rod, stick.

The type species is *Azotobacter chroococcum* Beijerinck.

1. **Azotobacter chroococcum** Beijerinck. (Cent. f. Bakt., II Abt., *7*, 1901, 567 and *9*, 1902, 3; *Bacillus azotobacter* Löhnis and Hanzawa, Cent. f. Bakt., II Abt., *42*, 1914, 1; *Bacillus chroococcus* Buchanan, General Syst. Bact., Baltimore, 1925, 194.) From Gr. *chroa*, color; *coccos*, grain; M. L. sphere.

According to Löhnis and Smith (Jour. Agr. Res., *23*, 1923, 401) *Azotobacter beijerinckii* Lipman (New Jersey Agr. Exp. Sta. Rept., *25*, 1904, 247), *Azotobacter woodstownii* Lipman (*ibid.*), *Azotobacter smyrnii* Lipman and Burgess (Cent. f. Bakt., II Abt., *44*, 1915, 504) and *Azotobacter hilgardii* Lipman (Science, *29*, 1909, 941) are identical with *Azotobacter chroococcum*. Greene (Soil Sci., *39*, 1935, 327) studied *Azotobacter chroococcum* and *Azotobacter beijerinckii* by chemical analyses and found the chemical composition of the cells to be practically identical, but different from that of *Azotobacter vinelandii* and *Azotobacter agile*. Smith (private communication) feels that *Azotobacter beijerinckii* is a non-pigmented rough strain of *Azotobacter chroococcum*.

Grows in absence of organic nitrogen.

Rods: 2.0 to 3.0 by 3.0 to 6.0 microns, occurring in pairs and packets and occasionally in chains. The cells show three or four refractile granules. The organisms are surrounded by a slimy membrane of variable thickness, usually becoming brownish in older cultures, due possibly to the conversion of tyrosine to melanin. The coloring matter is insoluble in water, alcohol, ether and chloroform. Motile by means of numerous peritrichous flagella (Hofer, Jour. Bact., *47*, 1944, 415.) Gram-negative.

Gelatin colonies: Very small, circular, yellow, granular, later becoming yellowish-brown.

Gelatin stab: Only slight growth in the stab. No liquefaction.

Mannitol agar stab: Gray, may become brownish.

Nutrient broth: No growth even in the presence of glucose; peptone utilized with difficulty.

Litmus milk: Becoming clearer in 10 to 14 days.

Potato: Glossy, barely visible, slimy

* Revised by Dr. A. W. Hofer, New York State Experiment Station, Geneva, New York, June, 1938; further revision by Dr. A. W. Hofer, July, 1943.

to wrinkled; may become yellowish, brownish-yellow or chocolate brown.

The organism fixes atmospheric nitrogen and gives off CO_2, utilizing glucose and sucrose. Other generally used carbon compounds are fructose, maltose, mannitol, inulin, dextrin, galactose, arabinose, starch, glycerol, ethyl alcohol, acetate, butyrate, citrate, lactate, malate, propionate and succinate.

Nitrate: Improves growth in amounts less than 1 gm. per liter; greater amounts are toxic.

Fixes nitrogen moderately actively.

Chemical analysis: Four-day cultures grown upon mannitol agar (Greene, 1935), when dried, are found to contain less than 0.5 per cent of hemicelluloses, less than 20 per cent of crude protein, less than 5 per cent of ash, and more than 30 per cent of lignin-like materials. The nitrogen fraction contains less than 1 per cent of amide nitrogen, less than 1 per cent of humin nitrogen and about 1 per cent of basic nitrogen.

Aerobic.

Optimum temperature 25°C. to 28°C.

Distinctive characters: Inability to grow in peptone media, even in the presence of glucose; frequent occurrence of a dark brown or black pigment.

Source: Isolated from soil.

Habitat: Occurs naturally in the majority of neutral or alkaline field soils.

2. **Azotobacter agile** Beijerinck. (Cent. f. Bakt., II Abt., 7, 1901, 577.) From L. *agilis*, agile, quick.

In studies on the chemical composition of cells Greene (Soil Sci., *39*, 1935, 327) found *Azotobacter vinelandii* Lipman (New Jersey Agr. Exp. Sta. Rept., *24*, 1903, 238) to be very similar to *Azotobacter agile* Beijerinck. Smith and Löhnis (Jour. Agr. Res., *23*, 1923, 401) agree and state furthermore that the two are identical; they believe also that *Azotobacter vitreum* Löhnis and Westermann (Cent. f. Bakt., II Abt., *22*, 1908, 234) is another synonym of *Azotobacter agile*. Smith (private communication) states that *Azotobacter vitreum* is a very weak growing, smooth strain of *Azotobacter agile*. Kluyver and van Reenen (Arch. Mikrobiol., *4*, 1933, 299) feel that a distinction should be made between *Azotobacter agile* and *Azotobacter vinelandii*. In regard to the former, Kluyver and van den Bout (Arch. Mikrobiol., 7, 1936, 263) suggest that it be further subdivided into *Azotobacter agile* and *Azotobacter agile* var. *atypica*, the latter referring to an *Azotobacter agile* form that fails to produce pigment.

Rods: 4 to 6 microns in length, almost spherical. Actively motile by means of numerous peritrichous flagella (Hofer, *loc. cit.*). Some strains are reported to be non-motile. Gram-negative.

Grows in absence of organic nitrogen.

Gelatin: No liquefaction.

Mannitol agar colonies: Circular, grayish white, translucent with whitish center.

Washed agar colonies: Show slight bluish-green fluorescence.

Mannitol agar slant: Grayish, translucent, fluorescent.

Plain agar slant: Yellowish-white, smooth, glistening, translucent with opaque center.

Broth: Turbid, with sediment.

Litmus milk: Becoming clear in 10 to 14 days.

Potato: Yellowish-white, slimy, becoming yellowish-brown.

In the presence of organic acids, a greenish or reddish pigment is formed.

The organism fixes atmospheric nitrogen actively, and gives off CO_2.

Aerobic.

Chemical analysis: Four-day cultures grown upon mannitol agar (Greene, 1935), when dried, contain more than 4 per cent of hemicelluloses, more than 45 per cent of crude protein, more than 7 per cent of ash, and less than 4 per cent of lignin-like materials. The nitrogen fraction contains more than 1 per cent amide nitrogen, more than 1 per cent humin

nitrogen, and 2 per cent or more of basic nitrogen.

Optimum temperature 25°C to 28°C.

Distinctive characters: Lack of a brown pigment; occasional fluorescence; growth in peptone broth containing glucose.

Source: Originally isolated from canal water at Delft.

Habitat: Occurs in water and soil.

3. **Azotobacter indicum** Starkey and De. (Soil Sci. *47*, 337, 1939.) From L. *indicus*, of India.

Rods: Ellipsoidal, from 0.5 to 1.2 by 1.7 to 2.7 microns when grown on nitrogen free glucose agar. One of the distinctive characteristics is the presence of two large, round, highly refractive bodies in the cells, one usually at each end. Motile by means of numerous peritrichous flagella (Hofer, *loc. cit.*). Gram-negative.

The organism grows slowly but in time produces large amounts of slime. Has high acid tolerance, since it grows from pH 3 to 9.

Sucrose or glucose agar plates: Colonies are colorless, round, very much raised, and uniformly turbid, having much the appearance of heavy starch paste. After two weeks, a buff to light brown color develops.

Mannitol agar slant: Grows very poorly.

Peptone agar slant with 0.5 per cent glucose: Limited grayish growth.

Nutrient broth: No growth.

Liquid media generally: Turbidity with some sediment.

Fixes atmospheric nitrogen readily with either glucose or sucrose as source of energy.

Aerobic.

Optimum temperature: 30°C.

Distinctive characters: Tolerance of acidity, wide limits of pH tolerated, abundant slime production, large globules of fat within cells.

Source: Soils of India.

Habitat: Soils.

Appendix I: The relationship of the following species to the species placed in *Azotobacter* is not yet entirely clear.

Genus Azotomonas *Stapp.*

(Cent. f. Bakt., II Abt., *102*, 1940, 18; not *Azotomonas* Orla-Jensen, Cent. f. Bakt., II Abt., *24*, 1909, 484.)

Rod to coccus-shaped aerobic bacteria, motile by means of 1 to 3 polar flagella. No endospores. No fat-like reserve food granules in the cells. Form acid and gas from glucose, and other sugars and alcohols. Form indole. Chemo-heterotrophic. Many carbon compounds other than sugars used as sources of energy. Active in the fixation of atmospheric nitrogen. Live in soil. From Gr. *azous*, not living, French, *azote*, nitrogen; Greek, *monas*, a unit; M. L. monad.

The type species is *Azotomonas insolita.*

Azotomonas insolita Stapp. (Abstracts of Communications, Third Internat. Congr. for Microbiol., Sect. VIII, 1939, 306; abst. in Proc. Soil Sci. Soc. of America, *4*, 1939, 244; Cent. f. Bakt., II Abt., 102, 1940, 1.) From Latin *insolitus*, unusual.

Coccoid rods: 0.6 to 1.2 by 0.6 to 1.8 microns. Motile with one to three polar flagella. Gram-negative.

Gelatin: No liquefaction.

Agar slant: Glistening white growth.

Agar colonies: Flat, whitish, edge entire. Weakly fluorescent.

Broth: Strong turbidity. Sediment. Pellicle.

Milk: No change.

Potato: Growth somewhat dry, not slimy, dirty gray, spreading.

Nitrites produced from nitrates.

Fixes nitrogen.

Ammonium salts utilized.

Acid and gas from adonitol, arabinose, dextrin, glucose, galactose, glycerine, inositol, lactose, fructose, maltose, mannitol, mannose, raffinose, rhamnose, salicin, sorbitol, starch, sucrose and xylose.

Starch is hydrolyzed.

Hydrogen sulfide produced.

Optimum temperature 25° to 30°C. Minimum 7° to 9.5°C. Maximum 48°C. Good growth at 37°C. Thermal death point 60°C.

Limits of pH 3.3 to 9.5.

Aerobic.

Source: From a mixture of chopped cotton husks and rice hulls.

Habitat: Soil.

FAMILY IV. RHIZOBIACEAE CONN.

(Jour. Bact., *36*, 1938, 321.)

Cells without endospores, rod-shaped, sparsely flagellated (one polar or lateral flagellum, or 2 to 4 peritrichous ones); some species non-motile. Usually Gram-negative. One genus (*Chromobacterium*) produces a violet pigment. Grow aerobically on ordinary culture media containing glucose. Glucose and sometimes other carbohydrates are utilized, without appreciable acid formation. Saprophytes, symbionts and pathogens. The latter are usually plant pathogens forming abnormal growths on roots and stems.

Key to genera of family **Rhizobiaceae.**

I. Cells capable of fixing free nitrogen when growing symbiotically on the roots of *Leguminosae*.

Genus I. *Rhizobium*, p. 223.

II. Either plant pathogens which attack roots or produce hypertrophies on stems; or free-living non-chromogenic soil or water forms. Do not fix nitrogen.

Genus II. *Agrobacterium*, p. 227.

III. Usually free-living soil and water forms which produce a violet chromogenesis.

Genus III. *Chromobacterium*, p. 231.

Genus I. **Rhizobium** *Frank.**

(*Phytomyxa* Schroeter, in Cohn, Kryptogamen-Flora von Schlesien, *3*, 1886, 134; Frank, Ber. d. deut. bot. Gesellsch., *7*, 1889, 380; *Rhizobacterium* Kirchner, Beitr. z. Biol. d. Pflanzen, *7*, 1895, 221; *Rhizomonas* Orla-Jensen, Cent. f. Bakt., II Abt., *22*, 1909, 328.) From Greek *rhiza*, root; *bios*, life.

Rods: 0.5–0.9 by 1.2–3.0 microns. Motile when young, commonly changing to bacteroidal forms (a) upon artificial culture media containing alkaloids or glucosides, or in which acidity is increased; or (b) during symbiosis within the nodule. Gram-negative. Aerobic, heterotrophic, growing best with extracts of yeast, malt or other plant materials. Nitrates may be reduced to nitrites. Nitrites are not utilized. Gelatin is not liquefied or is very slightly liquefied after long incubation. Optimum temperature 25°C. This group is capable of producing nodules on the roots of *Leguminosae*, and of fixing free nitrogen during this symbiosis.

The type species is *Rhizobium leguminosarum* Frank.

Key to the species of genus **Rhizobium.**

1. Litmus milk alkaline.
   a. Formation of serum zone in milk.
      b. Moderate growth, slight acid reaction on yeast water agar plus mono-, di- and trisaccharides.
         c. Causes formation of root nodules on species of the genera *Lathyrus*, *Pisum*, *Vicia* and *Lens*. Bacteroids irregular with x, y, star-, and club-shaped forms; rods peritrichous when young.
            1. *Rhizobium leguminosarum*.
         cc. Causes formation of root nodules on *Phaseolus vulgaris*, *P. multiflorus* and *P. angustifolius*. Bacteroids vacuolated rods, few branched forms; young cells peritrichous.
            2. *Rhizobium phaseoli*.

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* The genus *Rhizobium* was revised by Dr. and Mrs. O. N. Allen under the direction of Prof. E. B. Fred and Prof. I. L. Baldwin, Univ. of Wisconsin, Madison, Wis., Jan., 1938; further revision by Dr. O. N. Allen, Jan., 1943.

ccc. Causes formation of nodules on species of genus *Trifolium*. Bacteroids pear-shaped, swollen, vacuolated. Pentoses usually not fermented.

3. *Rhizobium trifolii.*

aa. No serum zone formed in milk.

b. Scant growth, alkaline reaction on yeast water agar plus most carbohydrates.

c. Causes formation of nodules on species of genus *Lupinus* and on *Ornithopus sativus*. Bacteroids vacuolated, rods seldom branched.

4. *Rhizobium lupini.*

cc. Causes formation of nodules on *Soja max*. Bacteroids long slender rods, seldom vacuolated or branched; young cells monotrichous.

5. *Rhizobium japonicum.**

2. Litmus milk acid.

a. Formation of serum zone in milk.

b. Moderate growth, slight acid reaction on yeast water agar plus mono-, di- and trisaccharides.

c. Causes formation of root nodules on species of the genera *Melilotus*, *Medicago*, and *Trigonella*. Bacteroids club-shaped, branched, young cells peritrichous.

6. *Rhizobium meliloti.*

1. **Rhizobium leguminosarum** Frank *emend.* Baldwin and Fred. (Frank, Landwirtschäftliche Jahrbücher, *19*, 1890, 563; *Rhizobium polymorphum* Dangeard, *Rhizobium fabae* Dangeard, Le Botaniste, Sér. *16*, 1926, 192–194; Baldwin and Fred, Jour. Bact., *17*, 1929, 146.) From Latin, of the legume family (*Leguminosae*).

NOTE: The following binomials have been used for species of this genus. The names given were used by their authors to cover one or more of the species here recognized as belonging to the genus *Rhizobium*. Where a question mark (?) is used it indicates that the species was too poorly described to be recognizable today. *Schinzia cellulicola* Frank, 1877 (all species) Leunis, Synopsis der drei Naturreiche. 2 Theil, Botanik, III Abt., Kryptogamen, Sec. 914, 1877, 1944; *Schinzia leguminosarum* Frank (all species), Bot. Ztg., *37*, 1879, 377; *Phytomyxa leguminosarum* Schroeter (all except *Rhizobium lupini*), in Cohn, Kryptogamen-Flora von Schlesien, *3*, I, 1886, 135; *Bacillus radicicola* Beijerinck (all species), Bot. Ztg., *46*, 1888, 726; *Bacillus fabae* Beijerinck (from broad bean) and *Bacillus ornithopi* Beijerinck (from serradella), Bot. Ztg., *48*, 1890, 837; *Cladochytrium tuberculorum* Vuillemin (all species?), Ann. Sci. Agron. Franc. et Étrang., *5*, I, 1888, 193; *Bacterium radicicola* Prazmowski (all species), Landw. Vers. Sta., *37*, 1890, 204; *Rhizobium mutabile* Schneider (several species) *Rhizobium curvum* Schneider (?), *Rhizo-*

* No specific name has been proposed for the organism causing the formation of nodules on plants that are members of the so-called "cowpea" group. Data showing possible inter-relationships of certain plant species of the soybean and cowpea cross-inoculation groups prompted Walker and Brown (Soil Science, *39*, 1935, 221–225) to propose a consolidation of the two groups to be recognized as being inoculated by a single species, *Rhizobium japonicum*. Results obtained recently by Reid and Baldwin (Proc. Soil Sci. Soc. Amer. for 1936, *1*, 1937, 219) show these inter-relationships to include the lupine group also.

bium frankii var. *majus* and var. *minus* Schneider (?), *Rhizobium nodosum* Schneider (?), *Rhizobium dubium* Schneider (?), Bul. Torrey Bot. Club, *19*, 1892, 213; *Rhizobium sphaeroides* Schneider (?), Ber. deut. bot. Gesell., *12*, 1894, 16; *Bacillus tuberigenus* Gonnermann and *Micrococcus tuberigenus* Gonnermann, Landw. Jahrb., *23*, 1894, 654, 657, are thought by Fred, Baldwin and McCoy (University of Wisconsin, Studies in Science, No. 5, 1932, 140) not to be true nodule organisms and to be too poorly described to be recognizable today; *Rhyzobium pasteurianum* Mazé (all species), Ann. Inst. Pasteur, *13*, 1899, 146; *Pseudorhizobium ramosum* Hartleb (?) (Chem. Zeit., *24*, 1900, 887) (used for noninfective culture claimed by Stutzer (Mitt. Landw. Inst. Breslau, *1*, Heft 3, 1900, 63) to be genuine root nodule organism); *Rhizobium radicicola* Hiltner and Störmer (several species) and *Rhizobium beijerinckii* Hiltner and Störmer (from lupine, serradella and soy bean), Arb. Biol. Abt. f. Land-u. Forstwirthschaft a. K. Gesundheitsamte, *3*, 1903, 269; *Pseudomonas radicicola* Moore (all species), U. S. Dept. Agr. Bur. Plant Ind., Bul. 71, 1905, 27; *Rhizomonas beijerinckii* Orla-Jensen and *Rhizomonas radicicola* Orla-Jensen (see Hiltner and Störmer), Cent. f. Bakt., II Abt., *22*, 1909, 328; *Bacillus* or *Bacterium radicicola* Löhnis and Hansen (peritrichous species), Jour. Agr. Research, *20*, 1921, 554; *Rhizobium radicicolum* Bergey et al., Manual, 1st ed., 1923, 40 (monotrichous species); *Rhizobium loti* Dangeard (from lotus), *Rhizobium simplex* Dangeard (from sainfoin), *Rhizobium torulosum* Dangeard (from Scotch broom), Le Botaniste, Sér. *16*, 1926, 195–197.

Rods: 0.5 to 0.9 by 1.2 to 3.0 microns. Motile with peritrichous flagella. Bacteroids commonly irregular with x, y, star- and club-shaped forms. Vacuolate forms predominate. Gram-negative.

Growth on mannitol agar is rapid, with tendency to spread. Streak is raised, glistening, semi-translucent, white, slimy and occasionally viscous. Considerable gum is formed.

Slight acid production from glucose, galactose, mannose, lactose and maltose.

Aerobic.

Optimum temperature 25°C.

Source: Root nodules on *Lathyrus*, *Pisum* (pea), *Vicia* (vetch) and *Lens* (lentil).

Habitat: Widely distributed in soils where the above mentioned legumes are grown

2. **Rhizobium phaseoli** Dangeard. (Le Botaniste, Sér. *16*, 1926, 197.) From Latin, *phaseolus*, bean; M. L. *Phaseolus*, a generic name.

Rods: Motile with peritrichous flagella. Bacteroids are usually rod-shaped, often vacuolated with few branched forms. Usually smaller than in *Rhizobium leguminosarum* and *R. trifolii*. Gram-negative.

Growth on mannitol agar is rapid with tendency to spread. Streak inoculation is raised, glistening, semi-translucent, white, slimy. Occasionally mucilaginous but this character is not so marked as in *Rhizobium trifolii*.

Very slight acid formation from glucose, galactose, mannose, sucrose and lactose.

Aerobic.

Optimum temperature 25°C.

Source: Root nodules of *Phaseolus vulgaris* (kidney bean), *P. angustifolius* (bean) and *P. multiflorus* (scarlet runner). (Burrill and Hansen, Ill. Agr. Exp. Sta. Bul. 202, 1917, 137.)

Habitat: Widely distributed in the soils in which beans are grown.

3. **Rhizobium trifolii** Dangeard. (Le Botaniste, Sér. *16*, 1926, 191.) From M. L. *Trifolium*, a generic name.

Rods: Motile with peritrichous flagella. Bacteroids from nodules are pear-shaped, swollen and vacuolated. Rarely x and y shapes. Gram-negative.

Growth on mannitol agar is rapid. The colonies are white becoming turbid with age. Frequently mucilaginous. Streak cultures transparent at first. Growth mucilaginous later flowing down the agar slant and accumulating as a slimy mass at the bottom. Produces large amounts of gum.

Slight acid production from glucose, galactose, mannose, lactose and maltose.

Aerobic.

Optimum temperature 25°C.

Source: Root nodules of species of *Trifolium* (clover).

Habitat: Widely distributed in the soils where clover grows.

4. **Rhizobium lupini** (Schroeter) Eckhardt, Baldwin and Fred. (*Phytomyxa lupini* Schroeter, in Cohn, Kryptogamen-Flora von Schlesien, *3*, I, 1886, 135; *Rhizobium minimum* Dangeard, Le Botaniste, Sér. *16*, 1926, 198; Eckhardt, Baldwin and Fred, Jour. Bact., *21*, 1931, 273.) From Latin, *Lupinus*, lupine.

Rods: Motile with flagella 1 to 4, usually 2 or 3. Bacteroids are vacuolate rods, seldom if ever branched. Gram-negative.

Growth on yeast water, mannitol agar is scant to moderate with alkaline reaction.

Beef-peptone gelatin: Little growth with extremely slow liquefaction.

On galactose an alkaline reaction serves to differentiate *Rhizobium lupini* from all fast-growing rhizobia (*R. phaseoli*, *R. meliloti*, *R. trifolii*, and *R. leguminosarum*). An initial alkaline reaction followed more quickly by an acid reaction on rhamnose and xylose separates *R. lupini* from slow-growing *R. japonicum* and the *Rhizobium sp.* from cow pea.

In general *Rhizobium lupini* produces slight to moderate acidity on pentose sugars and no change or alkaline reaction on hexoses, disaccharides and trisaccharides.

Litmus milk: No serum zone, no reduction, and a slight alkaline reaction.

Meager growth on potato and parsnip slants, and carrot agar.

Aerobic.

Optimum temperature 25°C.

Source: Root nodules on *Lupinus* (lupine), *Serradella* and *Ornithopus*.

Habitat: Widely distributed in soils in which these legumes grow.

5. **Rhizobium japonicum** (Kirchner) Buchanan. (*Rhizobacterium japonicum* Kirchner, Beiträge zur Biol. d. Pflanzen, *7*, 1895, 213; *Pseudomonas japonica* Löhnis and Hansen, *Bacterium japonicum* Löhnis and Hansen, Jour. Agr. Res., *20*, 1921, 551; *Rhizobium sojae* Dangeard, Le Botaniste, Sér. *16*, 1926, 200; Buchanan, Proc. Iowa Acad. Sci., *33*, 1926, 81.) From M. L., of Japan.

Rods: Motile with monotrichous flagella. Bacteroids of nodules are long and slender with only occasional branched and swollen forms. Gram-negative.

Growth on mannitol agar is slow and scant. The streak is slightly raised, glistening, opaque, white, butyrous, with little gum formation.

Pentose sugars give better growth than the hexoses.

Little if any acid formed from carbohydrates. Acid slowly formed from xylose and arabinose.

Aerobic.

Optimum temperature 25°C.

Source: Root nodules on *Soja max* (soy bean).

Habitat: Widely distributed in soils where soy beans are grown.

6. **Rhizobium meliloti** Dangeard. (Le Botaniste, Sér. *16*, 1926, 194.) From Greek, *melilot*, a kind of clover; M. L., *Melilotus*.

Rods: Motile with peritrichous flagella. Bacteroids club-shaped and branched. Gram-negative.

Growth on mannitol agar is fairly rapid. The streak is raised, glistening, opaque, pearly white, butyrous. Considerable gum is formed.

Acid from glucose, galactose, mannose and sucrose.

Aerobic.

Optimum temperature 25°C.

Source: Root nodules of *Melilotus* (sweet clover), *Medicago*, and *Trigonella*.

Habitat: Widely distributed in soils in which these legumes grow.

NOTE: See Monograph on Root Nodule Bacteria and Leguminous Plants by E. B. Fred, I. L. Baldwin and Elizabeth McCoy, University of Wisconsin Studies in Science, Madison, No. 5, 1932, xx + 343 pp. for a more complete discussion of this group with an extensive bibliography.

Genus II. Agrobacterium *Conn.**

(Jour. Bact., *44*, 1942, 359.) From Greek, *agrus*, a field; M.L., *bacterium*, a small rod.

Small, short rods which are typically motile with 1 to 4 peritrichous flagella (if only one flagellum, lateral attachment is as common as polar). Ordinarily Gram-negative. On ordinary culture media, they do not produce visible gas nor sufficient acid to be detectable by litmus. In synthetic media, enough CO_2 may be produced to show acid with brom thymol blue, or sometimes with brom cresol purple. Gelatin is either very slowly liquefied or not at all. Free nitrogen cannot be fixed; but other inorganic forms of nitrogen (nitrates or ammonium salts) can ordinarily be utilized. Optimum temperature, 25° to 30°C. Habitat: Soil, or plant roots in the soil; or the stems of plants where they produce hypertrophies.

The type species is *Agrobacterium tumefaciens* (Smith and Townsend) Conn.

Key to the species of genus Agrobacterium.

I. Plant pathogens. Produce browning of mannitol-calcium-glycerophosphate agar. Nitrate reduction weak or none.

A. Nitrite produced from nitrate to a slight extent. Galls produced on plant roots.
1. *Agrobacterium tumefaciens*.

B. Nitrite not produced from nitrate.

1. Pathogenic to apples.
2. *Agrobacterium rhizogenes*.

2. Pathogenic to raspberries and blackberries.
3. *Agrobacterium rubi*.

II. Not pathogenic to plants. Produces browning in mannitol-calcium-glycerophosphate agar. Nitrate reduction vigorous, with disappearance of the nitrate.
4. *Agrobacterium radiobacter*.

1. **Agrobacterium tumefaciens** (Smith and Townsend) Conn. (*Bacterium tumefaciens* Erw. Smith and Townsend, Science, N. S. *25*, 1907, 672; *Pseudomonas tumefaciens* Stevens, The Fungi which Cause Plant Disease, 1913, 35; *Bacillus tumefaciens* Holland, Jour. Bact., *5*, 1920, 220; not *Bacillus tumefaciens* Wilson, Lancet, *1*, 1919, 675; *Phytomonas tumefaciens* Bergey et al., Manual, 1st ed., 1923, 189; Conn, Jour. Bact., *44*, 1942, 359.) From Latin *tumefaciens*, swelling up, producing a tumor.

Probable synonyms: *Bacillus ampelopsorae* Trevisan, in Saccardo, Sylloge Fungorum, *8*, 1889, 983; *Bacillus ampelopsorae* Trevisan *emend.* Cavara, Staz. Sperim. Agara. Ital. Modena, *30*, 1897, 483; see Elliott, Bact. Plant Pathogens, 1930, 235.

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* Prepared by Prof. H. J. Conn, New York State Experiment Station, Geneva, New York, September, 1943.

Among the synonyms listed in previous editions of the Manual has been *Polymonas tumefaciens* Lieske, Cent. f. Bakt., I Abt., Orig., *108*, 1928, 118. This is only a partial synonym, however, as its author described it as the cause of animal and human cancer, of which he regarded crown-gall of plants as merely a phase: for the origin of this theory, see Smith and Townsend, Sci., N.S. *25*, 1907, 671, and Smith, Jour. Cancer Res., *7*, 1922, 1–105.

Description taken from the following: Riker, Banfield, Wright, Keitt and Sagen, Jour. Agr. Res., *41*, 1930, 507; Sagen, Riker and Baldwin, Jour. Bact., *28*, 1934, 571; Hendrickson, Baldwin and Riker, Jour. Bact., *28*, 1934, 597.

Rods: 0.7 to 0.8 by 2.5 to 3.0 microns, occurring singly or in pairs. Capsules. Motile with 1 to 4 flagella. Gram-negative.

Agar colonies: Small, white, circular, smooth, glistening, translucent, entire.

Broth: Slightly turbid, with thin pellicle.

Litmus milk: Slow coagulation. Litmus reduced. Neutral to alkaline.

Nitrites produced from nitrates to a very slight extent.

Indole: Slight amount.

Slight acid from glucose, fructose, arabinose, galactose, mannitol and salicin.

Starch not hydrolyzed.

Optimum temperature 25° to 28°C.

Facultative anaerobe.

Distinctive characters: Causes a gall formation parenchymatous in character which because of its soft nature is subject to injury and decay.

Agrobacterium tumefaciens strongly absorbs congo red and aniline blue in contrast to little or no absorption by *A. rhizogenes*. *A. tumefaciens* makes abundant growth on sodium selenite agar and calcium glycerophosphate medium with mannitol in contrast to no growth or a very slight trace by *A. rhizogenes* (Hendrickson et al., Jour. Bact., *28*, 1934, 597).

Source: Isolated from galls on plants.

Habitat: Causes galls on Paris daisy and cross-inoculable on over 40 families.

2. **Agrobacterium rhizogenes** (Riker et al.) Conn. (*Bacterium rhizogenes* Riker, Banfield, Wright, Keitt and Sagen, Jour. Agr. Res., *41*, 1930, 536; *Phytomonas rhizogenes* Riker et al., *ibid.*, 536; *Pseudomonas rhizogenes* Riker et al., *ibid.* 536; Conn, Jour. Bact., *44*, 1942, 359.) From Greek, *rhiza*, root; *genes*, producing.

Rods: 0.4 by 1.4 microns, occurring singly. Motile with one to 4 flagella. Encapsulated. Not acid-fast. Gram-negative.

Gelatin: No liquefaction.

Agar colonies: Circular, smooth, convex, finely granular; optical characters, translucent through gray to almost white.

Agar slant: Moderate, filiform, translucent, raised, smooth, slimy.

Broth: Turbid, with heavy pellicle.

Litmus milk: Acid, slow reduction.

Indole not formed.

Nitrites not produced from nitrates.

Acid but not gas from arabinose, xylose, rhamnose, glucose, galactose, mannose, maltose, lactose, salicin and erythritol. No acid or gas from fructose, sucrose, raffinose, melezitose, starch, dextrin, inulin, aesculin, dulcitol or mannitol.

Starch not hydrolyzed.

Optimum temperature 20° to 28°C.

Aerobic.

Distinctive characters: *Agrobacterium rhizogenes* differs from *Agrobacterium tumefaciens* by stimulating root formation instead of soft parenchymatous crown galls. *A. rhizogenes* lacks ability of *A. tumefaciens* to utilize simple nitrogenous compounds as KNO_3. *A. rhizogenes* absorbs congo red and brom thymol blue slightly and aniline blue not at all. Will not grow on sodium selenite agar (see *A. tumefaciens* for response to same materials). Does not infect tomato.

Sources: Description made from ten cultures isolated from hairy-root of apple and other plants.

Habitat: Pathogenic on apple, etc.

3. **Agrobacterium rubi** (Hildebrand) Starr and Weiss. (*Phytomonas rubi* Hildebrand, Jour. Agr. Res., *61*, 1940, 694; *Bacterium rubi* Hildebrand, *ibid.*, 694; *Pseudomonas rubi* Hildebrand, *ibid.*, 694; Banfield, Phytopath., *20*, 1930, 123; Pinckard, Jour. Agr. Res., *50*, 1935, 933; Starr and Weiss, Phytopath., *33*, 1943, 316.) From Latin, *rubus*, blackberry bush; M. L., *Rubus*, a generic name.

Rods: 0.6 by 1.7 microns. Singly, in pairs or short chains. Motile with 1 to 4 flagella. Gram-negative.

Gelatin: No liquefaction.

Potato-mannitol-agar slants: Growth slow, moderate, filiform, white to creamy-white, with butyrous consistency later becoming leathery.

Broth: Turbid in 36 to 48 hours.

Milk: A slight serum-zone, pink color, acid and curd formed.

Nitrites not produced from nitrates.

Ferric ammonium citrate, uric acid, oxamide, succinimide, l-asparagine, l-tyrosine, l-cystine, d-glutamic acid and yeast extract can be used as a source of nitrogen (Pinckard, *loc. cit.*).

Hydrogen sulfide not formed.

Indole not formed.

Acid from glucose, d-galactose, d-mannose, d-fructose, d-xylose, d-arabinose, sucrose, and maltose. None from lactose (Pinckard, *loc. cit.*).

Starch not hydrolyzed.

Optimum temperature 28°C. Minimum 8°C. and maximum 36°C. (Pinckard, *loc. cit.*).

Distinctive characters. Differs from *Agrobacterium tumefaciens* in that it does not utilize nitrates, and grows much more slowly on ordinary media. Infects only members of the genus *Rubus*. Starr and Weiss (Phytopath., *33*, 1943, 317) state that this species unlike *Agrobacterium tumefaciens* and *Agrobacterium rhizogenes* does not utilize asparagin as a sole source of carbon and nitrogen.

Source: Isolated by Banfield (*loc. cit.*) and by Hildebrand (*loc. cit.*) from raspberry canes, *Rubus spp.*

Habitat: Pathogenic on black and purple cane raspberries, and blackberries, and to a lesser extent on red raspberries.

4. **Agrobacterium radiobacter** (Beijerinck and van Delden) Conn. (*Bacillus radiobacter* Beijerinck and van Delden, Cent. f. Bakt., II Abt., *9*, 1902, 3; *Bacterium radiobacter* Löhnis, Cent. f. Bakt., II Abt., *14*, 1905, 589; *Rhizobium radiobacter* Pribram, Klassifikation der Schizomyceten, Leipzig, 1933,53; *Achromobacter radiobacter* Bergey et al., Manual, 4th ed., 1934, 230; *Alcaligenes radiobacter* Conn, in Manual, 5th ed., 1939, 97; Conn, Jour. Bact., *44*, 1942,359.) From Latin, *radius*, the spoke of a wheel; Latin, *bactrum*, a rod.

Small rods, 0.15 to 0.75 by 0.3 to 2.3 microns, occurring singly, in pairs and under certain conditions, in star-shaped clusters. Motile with one to four flagella. Prevailingly Gram-negative; but an occasional culture is variable.

Nutrient gelatin stab: No liquefaction.

Agar slant: Flat, whitish slimy layer.

Mannitol-calcium-glycerophosphate-agar streak plates: Abundant, raised, slimy growth surrounded by a brown halo with an outer zone of white precipitate (Riker et al., Jour. Agr. Res., *41*, 1930, 524).

Broth: Turbid; with heavy ring or pellicle if veal infusion is present.

Litmus milk: Serum zone with pellicle in one week; usually turns a chocolate brown in 2 weeks; same in plain milk, but with less browning.

Potato: Raised slimy mass becoming brownish; potato may be browned.

Nitrates disappear (assimilated or reduced).

Starch not hydrolyzed.

No organic acid or visible gas from sugars; nearly all sugars, glycerol and

mannitol are utilized with the production of CO_2.

Optimum temperature 28°C. Minimum near 1°C. Maximum 45°C.

Aerobic.

Media containing KNO_3, K_2HPO_4, and glycerol, ethyl or propyl alcohol become alkaline to phenol red. (Sagen, Riker and Baldwin, Jour. Bact., *28*, 1934, 571.)

Growth occurs in special alkaline media of pH 11.0 to 12.0 (Hofer, Jour. Amer. Soc. Agron., *27*, 1935, 228).

Hydrogen sulfide produced if grown in ZoBell and Feltham's medium (Jour. Bact., *28*, 1934, 169).

Distinctive characters: Browning of mannitol-calcium-glycerophosphate agar. Inability to cause plant disease or to produce nodules on roots of legumes. Complete utilization (disappearance of nitrate) in the peptone-salt medium of Riker et al. (Jour. Agr. Res., *41*, 1930, 529) and failure to absorb congo red (*ibid.*, 528).

The species bears at least superficial resemblances to certain *Rhizobium spp.*, but may be distinguished from them by the first two characters listed above, and the following in addition: Growth at a reaction of pH 11–12. Heavy ring or pellicle formation on veal infusion broth. H_2S production in the mannitol-tryptone medium of ZoBell and Feltham (*loc. cit.*). Production of milky white precipitate on nitrate-glycerol-soil-extract agar.

Source: Isolated from soil.

Habitat: Soil, around the roots of plants, especially legumes.

NOTE: Palacios and Bari (Proc. Indian Acad. Sci., *3*, 1936, 362; Abs. in Cent. f. Bakt., II Abt., *95*, 1937, 423) have described *Bacillus concomitans* as a symbiont from legume nodules that has no power to fix nitrogen although it is very much like legume nodule bacteria (*Rhizobium spp.*). This organism resembles *Agrobacterium radiobacter*.

Appendix: The following species probably belong in *Agrobacterium*, but are not sufficiently well described to make their relationship certain.

1. **Agrobacterium gypsophilae** (Brown) Starr and Weiss. (*Bacterium gypsophilae* Brown, Jour. Agr. Res., *48*, 1934, 1109; *Pseudomonas gypsophilae* Stapp, Bot. Rev., *1*, 1935, 407; *Phytomonas gypsophilae* Stapp, *ibid.*, 407; Starr and Weiss, Phytopath., *33*, 1943, 316.) From M. L., *Gypsophila*, a generic name.

Rods: 0.2 to 0.8 by 0.4 to 1.4 microns. Motile with 1 to 4 flagella. Capsules. Gram-negative.

Gelatin: Liquefaction slow, beginning after 1 month.

Beef-infusion agar colonies: Circular, Naples yellow, smooth or rough, butyrous.

Broth: Turbid in 24 hours.

Milk: Coagulation and peptonization.

Nitrites are produced from nitrates.

Indole not produced.

Hydrogen sulfide: A trace may be produced.

Acid but not gas from glucose, sucrose, maltose, mannitol and glycerol. No acid from lactose.

Starch not hydrolyzed.

Aerobic, facultative.

Distinctive characters: Differs from *Xanthomonas beticola* in starch hydrolysis, H_2S production, and will not cross-inoculate with this species.

Source: Isolated from several galls on *Gypsophila*.

Habitat: Produces galls in *Gypsophila paniculata* and related plants.

2. **Bacterium pseudotsugae** Hansen and Smith. (Hansen and R .E. Smith, Hilgardia, *10*, 1937, 576; *Phytomonas pseudotsugae* Burkholder, in Manual, 5th ed., 1939, 209.) From M. L., *Pseudotsuga*, a generic name.

Rods: 0.5 to 1.5 by 1.9 to 3.9 microns. Probably motile; type of flagellation doubtful. Gram-negative.

Gelatin: Liquefied.

Nutrient agar slant: Growth scanty, flat, glistening, smooth, translucent, whitish.

Broth: Growth slight. No sediment.

Milk: No acid.

Nitrites produced from nitrates.

Hydrogen sulfide production slight.

Acid but not gas from glucose, fructose, galactose and maltose. No acid or gas from lactose, sucrose or glycerol.

Starch not hydrolyzed.

Facultative aerobe.

Source: Isolated from galls on Douglas fir in California.

Habitat: Pathogenic on Douglas fir, *Pseudotsuga taxifolia*.

Genus III. **Chromobacterium** *Bergonzini.**

(Ann. Societa d. Naturalisti in Modena, Ser. 2, *14*, 1881, 153.) Greek, *chroma*, color; M. L., *bacterium*, a small rod.

Rods, 0.4 to 0.8 by 1.0 to 5.0 microns. Motile with 1 to 4 or more flagella. Gram-negative. A violet pigment is formed which is soluble in alcohol, but not in water or chloroform. Grow on ordinary culture media, usually forming acid from glucose, sometimes from maltose, not from lactose. Gelatin is liquefied. Indole is not produced. Nitrate usually reduced to nitrite. Optimum temperature 20–25°C. but some grow well at 37°C. Usually saprophytic soil and water bacteria.

The type species is *Chromobacterium violaceum* (Schroeter) Bergonzini.

Key to the species of genus **Chromobacterium.**

I. Motile rods. Single flagellum.
 A. Acid from glucose and maltose. No acid from sucrose. Nitrites produced from nitrates. No growth at 37°C.
  1. *Chromobacterium violaceum.*

II. Motile rods. Flagella generally peritrichous.
 A. Acid from glucose. Nitrites generally not produced from nitrates. Good growth at 37°C.
  2. *Chromobacterium ianthinum.*
 B. Generally no acid from glucose. Nitrites produced from nitrates. No growth at 37°C.
  3. *Chromobacterium amethystinum.*

1. **Chromobacterium violaceum** (Schroeter) Bergonzini. (*Bacteridium violaceum* Schroeter, Beiträge z. Biol. d. Pflanzen, *1*, Heft 2, 1872, 126; *Micrococcus violaceus* Cohn, Beiträge z. Biol. d. Pflanzen, *1*, Heft 2, 1872, 157; *Cromobacterium violaceum* (sic) Bergonzini, Ann. Societa d. Naturalisti in Modena, Ser. 2, *14*, 1881, 153; *Bacillus violaceus* Schroeter, Kryptogamen-Flora von Schlesien, *3*, 1886, 157; *Streptococcus violaceus* Trevisan, I generi e le specie delle Batteriacee, 1889, 31; *Pseudomonas violacea* Migula, Arb. a. d. Bakt. Inst. Karlsruhe, *1*, 1894, 237; *Bacterium violaceum* Lehmann and Neumann, Bakt. Diag., 1 Aufl., *2*, 1896, 58; see 2 Aufl., *2*, 1899, 262.) From Latin, *violaceus*, violet-colored.

NOTE: *Bacterium ianthinum* Zopf (Die Spaltpilze, 1885, 68) has been regarded as identical with the above organism by Schroeter (Kryptogamen-Flora von Schlesien, *3*, 1, 1886, 157), and by Leh-

* Adapted by Prof. Robert S. Breed, New York State Experiment Station, Geneva, New York from Cruess-Callaghan and Gorman, Scientific Proc. Royal Dublin Society, *21*, 1935, 213 in Jan. 1938; further revision, July, 1945 by Robert S. Breed with the assistance of Capt. W. C. Tobie, Sn. C., Old Greenwich, Conn.

mann and Neumann (Bakt. Diag., 1 Aufl., *2*, 1896, 266; also 7 Aufl., *2*, 1927, 463). Lehmann and Neumann (*loc. cit.*) also consider *Bacillus violaceus laurenticus* Lustig (Diagnostik der Bakterien des Wassers, 1893, 103) as being identical with *Bacterium violaceum.*

Slender rods: 0.8 to 1.0 by 2.0 to 5.0 microns, occurring singly and in chains. Motile, with a single flagellum. Gram-negative.

Gelatin colonies: Circular, gray, entire margin, assuming a violet color in the center.

Gelatin stab: Infundibuliform liquefaction with violet sediment in fluid.

Agar colonies: Whitish, flat, glistening, moist, becoming violet.

Agar slant: Deep, violet, moist, shiny spreading growth.

Broth: Slightly turbid, with violet ring and ropy sediment.

Litmus milk: Violet pellicle. Digestion. Alkaline.

Potato: Limited, dark violet growth.

Löffler's blood serum: Slowly liquefied.

Indole not formed.

Nitrites produced from nitrates.

Acid from glucose and usually from maltose. No acid from lactose or sucrose.

Aerobic, facultative.

Optimum, temperature 25° to 30°C. No growth at 37°C. Slight growth at 2° to 4°C.

Source: Originally grown on slices of cooked potato exposed to air contamination, and incubated at room temperature.

Habitat: Water.

2. **Chromobacterium ianthinum** (Zopf) Holland. (*Bacterium ianthinum* Zopf, Die Spaltpilze, 2 Aufl., 1884, 62; *Bacillus janthinus* Flügge, Die Mikroorganismen, 1886, 291; *Bacteridium ianthinum* Schroeter, Kryptogamen Flora von Schlesien, *3*, 1, 1886, 157; *Pseudomonas ianthina* Migula, Syst. d. Bakt., *2*, 1900, 941; *Pseudomonas janthina* Chester, Man. Determ. Bact., 1901, 317; Holland, Jour. Bact., *5*, 1920, 222.) From Greek, *ianthinus*, violet-blue.

Rods: 0.5 to 0.8 by 1.5 to 5.0 microns, occurring singly. Motile with peritrichous flagella. Gram-negative.

Gelatin colonies: Circular, yellow, becoming violet.

Gelatin stab: White to violet surface growth. Infundibuliform liquefaction.

Agar colonies: Creamy center, violet margin.

Agar slant: Yellowish, moist, glistening, becoming deep violet.

Broth: Turbid, with light violet pellicle.

Litmus milk: Slow coagulation with violet cream layer. Litmus decolorized from below.

Potato: Violet to violet-black, spreading growth.

Indole not formed.

Nitrites generally not produced from nitrates.

Acid from glucose. No acid from maltose, lactose and sucrose.

Aerobic, facultative.

Optimum temperature 30°C. Grows well at 37°C. No growth at 2 to 4°C.

Source: Originally grown on pieces of pig's bladder floated on badly contaminated water.

Habitat: Water and soil. This may be the species that causes a fatal septicemia in animals and man. See *Chromobacterium violaceum manilae.*

3. **Chromobacterium amethystinum** (Chester) Holland. (*Bacillus membranaceus amethystinus* Eisenberg, Bakt. Diag., 1891, 421; *Bacterium amethystinus* Chester, Ann. Rept. Del. Col. Agr. Exp. Sta., *9*, 1897, 117; *Bacterium membranaceus amethystinus* Chester, *ibid.*, 138; *Bacillus amethystinus* Holland, Jour. Bact., *5*, 1920, 217; not *Bacillus amethystinus* Chester, *loc. cit.*, 262; Holland, *loc. cit.*, 222; *Bacterium membranaceum amethystinum* Lehmann and Neumann, Bakt. Diag., 7 Aufl., *2*, 1927, 463; *Bacterium violaceum amethystinum* Cruess-Callaghan and Gorman, Sci. Proc. Royal Dublin Society, *21*, 1935, 219.) From Greek, bluish-violet, amethyst.

Rods: 0.5 to 0.8 by 1.0 to 1.4 microns, occurring singly. Motile with a single or occasionally with peritrichous flagella. Gram-negative.

Gelatin colonies: Thin, bluish, becoming violet, crumpled.

Gelatin stab: Heavy, violet-black pellicle. Liquefied.

Agar colonies: Deep violet, surface rugose.

Agar slant: Thick, moist, yellowish-white, becoming violet with metallic luster.

Broth: Pellicle with violet sediment, fluid becoming violet.

Litmus milk: Violet pellicle. Digestion turning alkaline.

Potato: Deep violet, rugose spreading growth.

Indole not formed.

Nitrites produced from nitrates.

Usually no acid from glucose, maltose and sucrose. No acid from lactose.

Aerobic, facultative.

Optimum temperature 30°C. No growth at 37°C. Good growth in 7 days at 2 to 4°C.

Original source: Found once by Jolles in spring water from Spalato.

Habitat: Water.

Appendix: The following organisms have been assigned to this genus or are believed to belong here. Additional comparative studies are badly needed.

Bacillus cyaneo-fuscus Beijerinck. (Beijerinck, Bot. Ztung., *49*, 1891, 704; *Bacterium cyanofuscus* Chester, Ann. Rept. Del. Col. Agr. Exp. Sta., *9*, 1897, 116 and 132.) From black glue, blue Edam cheese, water and soil.

Bacillus lacmus Schroeter. (Schroeter in Cohn, Kryptogamen-Flora von Schlesien, *3*, 1, 1889, 158.) In greenhouse on fresh paint.

Bacillus lilacinus Macé. (Traité Pratique Bact., 6ᵉ éd., *2*, 1913, 416.) From water.

Bacillus membranaceus amethystinus mobilis Germano. (Germano, Cent. f. Bakt., *12*, 1892, 516; *Bacillus amethystinus mobilis* Kruse, in Flügge, Die Mikroorganismen, 3 Aufl., *2*, 1896, 313; *Bacterium amethystinus mobilis* Chester, Ann. Rept. Del. Col. Agr. Exp. Sta., *9*, 1897, 117; *Bacterium membranaceus mobilis* Chester, *ibid.*, 138.) *Pseudomonas amethystina* Migula, Syst. d. Bakt., *2*, 1900, 944; *Bacillus amethystinus* Chester, Man. Determ. Bact., 1901, 262.) From dust.

Bacillus pavoninus Forster. (Forster, in van der Sleen, Sur l'examen bactériologique qualitatif de l'eau. Arch. Teyler, Sér. 2, Tome 4, 3 partie, 1894, No. 59, Haarlem, Heritiere Loosjes. Also see Godfrin, Thése, Nancy, 1934, 46.) Causes blue discoloration of Edam cheese.

Bacillus polychromogenes Chamot and Thiry. (Bacille polychrome, Thiry, Compt. rend. Soc. Biol., Paris, *48*, 1896, 885; Chamot and Thiry, Bot. Gaz., *30*, 1900, 378.) From well water at Nancy. Probably a *Pseudomonas* (Tobie, personal communication).

Bacillus violaceus Frankland and Frankland. (Frankland and Frankland, Ztschr. f. Hyg., *6*, 1888, 394; *Pseudomonas pseudoianthina* Migula, Syst. d. Bakt., *2*, 1900, 942.) Isolated from tap water. Said to produce spores.

Bacillus violaceus laurentius Jordan. (Jordan, Mass. State Bd. Health Rept., 1890, 838; *Bacterium violaceus laurentius* Chester, Ann. Rept. Del. Col. Agr. Exp. Sta., *9*, 1897, 117; *Pseudomonas laurentia* Migula, Syst. d. Bakt., *2*, 1900, 944; *Bacillus violaceus* Chester, Man. Determ. Bact., 1901, 262; *Chromobacterium violaceum laurentium* Ford, Textb. Bact., 1927, 470.) Isolated from sewage effluent.

Bacillus violaceus lutetiensis Kruse. (Kruse, in Flügge, Die Mikroorganismen, 3 Aufl., *2*, 1896, 311; *Bacillus lutetiensis* Chester, Man. Determ. Bact., 1901, 306; *Chromobacterium violaceum lutetiense* Ford, Textb. Bact., 1927, 470.) From water.

Bacillus violaceus sartoryi Waeldele. (Thèse, Pharm. Strasbourg, 1938, 55.)

From dental pus. Said to form spores.

Bacterium cristallino violaceum Cholkevitch. (Cholkevitch, 1922, quoted from Godfrin, Contribution a l'étude des bactéries bleues et violettes. Thése, Nancy, 1934, 93.) From peat.

Chromobacterium bamptonii Bergey et al. (*Bacillus membranaceus amethystinus II*, Bampton, Cent. f. Bakt., I Abt., Orig., *71*, 1913, 137; Bergey et al., Manual, 1st ed., 1923, 119; *Chromobacterium membranaceum amethystinum II* Ford, Textb. Bact., 1927, 473.) From water.

Chromobacterium coeruleum (Voges) Bergey et al. (*Bacillus coeruleus* Voges, Cent. f. Bakt., *14*, 1893, 303; *Bacterium coeruleus* Chester, Ann. Rept. Del. Col. Agr. Exp. Sta., *9*, 1897, 117; *Pseudomonas coerulea* Migula, Syst. d. Bakt., *2*, 1900, 945; Bergey et al., Manual, 1st ed., 1923, 120.) From water.

Chromobacterium cohaerens Grimes. (Sci. Proc. Royal Dublin Society, *19*, 1930, 381.) From well water.

Chromobacterium hibernicum Grimes. (Sci. Proc. Royal Dublin Society, *19*, 1930, 381.) From well water.

Chromobacterium lividum (Voges) Holland. (Plagge and Proskauer, Zeitsch. f. Hyg., *2*, 1887, 463; *Bacillus lividus* Voges, Cent. f. Bakt., *14*, 1893, 303; relationship to *Bacillus lividus* Zimmermann uncertain. Die Bakt. unserer Trink- und Nutzwässer, Chemnitz, *2*, 1894, 18; *Bacillus violaceus berolinensis* Kruse, in Flugge, Die Mikroorganismen, 3 Aufl., *2*, 1896, 311; *Bacterium lividus* Chester, Ann. Rept. Del. Col. Agr. Exp. Sta., *9*, 1897, 117; *Bacillus berolinensis* Chester, Man. Determ. Bact., 1901, 305; Holland, Jour. Bact., *5*, 1920, 215.) From water.

Chromobacterium maris-mortui Elazari-Volcani. (Studies on the Microflora of the Dead Sea, Thesis, Hebrew Univ., Jerusalem, 1940, vii and 76.) From the Dead Sea.

Chromobacterium membranaceum Bergey et al. (*Bacillus membranaceus amethystinus I*, Bampton, Cent. f. Bakt., I Abt., Orig., *71*, 1913, 135; Bergey et al., Manual, 1st ed., 1923, 119; *Chromobacterium membranaceum amethystinum I* Ford, Textb. Bact., 1927, 472.) From water.

Chromobacterium membranaceum amethystinum III Ford. (Ford, Textb. Bact., 1927, 474; *Bacillus membranaceus amethystinus III* Bampton, Cent. f. Bakt., I Abt., Orig., *71*, 1913, 138.) From water.

Chromobacterium membranaceum amethystinum IV Ford. (Ford, Textb. Bact., 1927, 474; *Bacillus membranaceus amethystinus IV* Bampton, Cent. f. Bakt., I Abt., Orig., *71*, 1913, 138.) From water.

Chromobacterium smithii (Chester) Bergey et al. (*Bacillus coeruleus* Smith, Medical News, *2*, 1887, 758; *Bacterium coeruleus* Chester, Ann. Rept. Del. Col. Agr. Exp. Sta., *9*, 1897, 118; *Pseudomonas smithii* Chester, Man. Determ. Bact., 1901, 318; *Chromobacterium coeruleum* Ford, Textb. Bact., 1927, 475; not *Chromobacterium coeruleum* Bergey et al., Manual, 1st ed., 1923, 120; Bergey et al., *ibid.*, 121.) From water.

Chromobacterium violaceum manilae Ford. (*Bacillus violaceus manilae* Woolley, U. S. Dept. Int., Bur. Govt. Labs. Bull. 15, 1904 and Bull. Johns Hopkins Hosp., *16*, 1905, 89; Ford, Textb. Bact., 1927, 471.) Isolated from fatal septicemias in water buffalo (Woolley) and man (Schattenberg and Harris, Jour. Bact., *44*, 1942, 509). More likely to be a variety of *Chromobacterium ianthinum* which grows at 37°C. than of *C. violaceum* which does not grow at 37°C.

Chromobacterium viscofucatum (Harrison and Barlow) Bergey et al. (*Bacterium viscofucatum* and *Bacillus viscofucatus* Harrison and Barlow, Cent. f. Bakt., II Abt., *15*, 1905, 517; Trans. Royal Soc. Canada, 2nd Ser., *11*, 1905; Bergey et al., Manual, 1st ed., 1923, 119.) From oily butter. Probably a non-motile *Pseudomonas* (Tobie, personal communication).

Chromobacterium viscosum Grimes. (Cent. f. Bakt., II Abt., *72*, 1927, 367.) From butter.

Pseudomonas pseudoviolacea Migula. (Syst. d. Bakt., *2*, 1900, 943.) From river water.

FAMILY V. MICROCOCCACEAE PRIBRAM.*

(Jour. Bact., *18*, 1929, 385.)

Cells without endospores except in *Sporosarcina*. Cells in their free condition spherical; during division somewhat elliptical. Division in two or three planes. If the cells remain in contact after division, they are frequently flattened in the plane of last division. They occur singly, in pairs, tetrads, packets or irregular masses. Motility rare. Generally Gram-positive. Many species form a yellow, orange, pink or red pigment. Most species are preferably aerobic, producing abundant growth on ordinary culture media, but capable of slight anaerobic growth. A few species are strictly anaerobic. Metabolism heterotrophic. Carbohydrates are frequently fermented to acid. Gelatin is often liquefied. Facultative parasites and saprophytes. Frequently live on the skin, in skin glands or skin gland secretions of *Vertebrata*.

Key to the genera of family Micrococcaceae.

I. Cells occur in plates, groups or in irregular packets and masses, never in chains. Pigment, when present, is yellow, orange or red. Gram-positive to Gram-negative.

Genus I. *Micrococcus*, p. 235.

II. On the animal body and in special media cells occur as tetrads. In ordinary media cells may occur in pairs and irregular masses. White to pale yellow.

Genus II. *Gaffkya*, p. 283.

III. Cells occur in regular packets. Yellow or orange pigment usually formed.

Genus III. *Sarcina*, p. 285.

Genus I. Micrococcus *Cohn.**

(Cohn, Beiträge z. Biol. d. Pflanzen, *1*, Heft 2, 1872, 153; *Microsphaera* Cohn, Arch. f. path. Anat., *55*, 1872, 237; not *Microsphaera* Léveillé, Ann. Sci. Nat. Bot., Sér. 3, *16*, 1851, 381; *Ascococcus* Cohn, Beiträge z. Biol. d. Pflanzen, *1*, Heft 3, 1875, 154; *Pediococcus* Balcke, Wchnschr. f. Brauerei, *1*, 1884, 183; *Merista* Van Tieghem, Traité de Botanique, Paris, 1884, 1114; *Staphylococcus* Rosenbach, Mikroorganismen bei den Wundinfektions-krankheiten des Menschen, 1884, 27; *Monococcus* Miller, Deutsch. med. Wchnschr., *12*, 1886, No. 8, 117; *Botryomyces* Bollinger, Deutsch. Ztschr. f. Tiermed., *13*, 1887, 77; *Urococcus* Miquel, Ann. Microg., *1*, 1888, 518; *Galactococcus* Guillebeau, Jahrb. d. Schweiz, *4*, 1890, 32; *Rhodococcus* Zopf, Ber. d. deutsch. Bot. Gesellsch., Berlin, *9*, 1891, 28; *Pyococcus* Ludwig, Lehrb. d. niederen Kryptog., 1892, 27; *Planococcus* Migula, Arb. Bakt. Inst. Karlsruhe, *1*, 1894, 236; *Carphococcus* Hohl, Cent. f. Bakt., II Abt., *9*, 1902, 338; *Albococcus* Winslow and Rogers, Jour. Inf. Dis., *3*, 1906, 541; *Aurococcus* Winslow and Rogers, *ibid.*, 540; *Pedioplana* Wolff, Cent. f. Bakt., II Abt., *18*, 1907, 9; *Melococcus* Nedrigailov, Charkov Med. Zurnal, *4*, 1907, 301; *Solidococcus*, *Liquidococcus*, *Indolococcus* and *Peptonococcus* Orla-Jensen, Cent. f. Bakt., II Abt., *22*, 1909, 332; *Planomerista* Vuillemin, Ann. Mycol., *11*, 1913, 525; *Tetracoccus* Orla-Jensen (in part), The Lactic Acid Bacteria, 1919, 76.) From Greek *micrus*, small; *coccus*, a grain; M. L., a sphere.

Cells in plates or irregular masses (never in long chains or packets). Gram-positive to Gram-negative. Growth on agar usually abundant, some species form no

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* The genera *Micrococcus* and *Staphylococcus* have been combined and completely revised by Prof. G. J. Hucker, New York State Experiment Station, Geneva, New York, March, 1943 so far as the aerobic species are concerned. Dr. Ivan C. Hall, Presbyterian Hospital, New York City, revised the anaerobic section, January, 1944.

pigment but others form yellow or less commonly orange, or red pigment. Glucose broth slightly acid, lactose broth generally neutral. Gelatin frequently liquefied, but not rapidly. Facultative parasites and saprophytes.

The type species is *Micrococcus luteus* (Schroeter) Cohn.

Key to the species of genus **Micrococcus.**

1. Aerobic to facultative anaerobic species.
   I. No pink or red pigment on agar media.
      A. Nitrites not produced from nitrates.
         1. Utilize $NH_4H_2PO_4$ as sole source of nitrogen.*
            a. Yellow pigment on agar media. Not acido-proteolytic.
               1. *Micrococcus luteus.*
            aa. No pigment produced. Not acido-proteolytic.
               b. Utilizes urea as a sole source of nitrogen.**
                  2. *Micrococcus ureae.*
               bb. Does not utilize urea.
                  3. *Micrococcus freudenreichii.*
            aaa. Acido-proteolytic in litmus milk.
               8. *Micrococcus caseolyticus.*
         2. Do not utilize $NH_4H_2PO_4$ as sole source of nitrogen.
            a. Yellow pigment produced.
               4. *Micrococcus flavus.*
            aa. No pigment produced.
               5. *Micrococcus candidus.*
      B. Nitrites produced from nitrates.
         1. Utilize $NH_4H_2PO_4$ as sole source of nitrogen.
            a. Yellow pigment on agar media. Not acido-proteolytic.
               b. Gelatin liquefied.
                  6. *Micrococcus conglomeratus.*
               bb. Gelatin not liquefied.
                  7. *Micrococcus varians.*
            aa. Usually not chromogenic. Actively acido-proteolytic in litmus milk.
               8. *Micrococcus caseolyticus.*
         2. Do not utilize $NH_4H_2PO_4$ as sole source of nitrogen.
            a. Gelatin liquefied. Ferment mannitol.
               b. Abundant orange growth on agar media.
                  9a. *Micrococcus pyogenes* var. *aureus.*
               bb. Abundant white growth on agar media.
                  9b. *Micrococcus pyogenes* var. *albus.*
               bbb. Yellow growth on agar media.
                  10. *Micrococcus citreus.*
            aa. Gelatin not liquefied or very slowly liquefied.
               b. Abundant orange to white growth on agar media. Ferments mannitol.
                  11. *Micrococcus aurantiacus.*
               bb. Scant white translucent growth on agar media. Does not ferment mannitol.
                  12. *Micrococcus epidermidis.*

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* That is, will grow and produce acid (sometimes slowly) on slants containing 1.5 per cent washed agar, 0.1 per cent ammonium phosphate, 1.0 per cent glucose, 0.02 per cent potassium chloride, 0.02 per cent magnesium sulfate. Add brom-cresol-purple as an indicator (Hucker, N. Y. State Exper. Sta., Tech. Bul. 100, 1924, 25; Tech. Bul. 101, 1924, 36–40); Manual Pure Culture Study of Bacteria. Soc. Amer. Bact., Geneva, N. Y., Leaflet II, 9th ed., 1944, 14.)

** Substitute 0.1 per cent urea for the ammonium phosphate in the above medium.

II. Pink or red pigment on agar media.
  A. Gelatin liquefied, slowly. Produces rose-colored pigment.
    13. *Micrococcus roseus.*
  B. Gelatin not liquefied.
    1. Non-motile.
      a. Produces cinnabar-colored pigment on gelatin.
        14. *Micrococcus cinnabareus.*
      aa. Produces light, flesh-colored pigment on agar slant. Ferments glycerol and mannitol.
        15. *Micrococcus rubens.*
      aaa. Produces brick-colored pigment on agar slant. Does not ferment glycerol and mannitol.
        16. *Micrococcus rhodochrous.*
    2. Motile. Produces red pigment.
      17. *Micrococcus agilis.*

2. Anaerobic species.
  I. Forms gas from nitrogenous media.
    A. Acid from glucose.
      18. *Micrococcus aerogenes.*
    B. No acid from glucose.
      1. No blackening of colonies in deep agar.
        19. *Micrococcus asaccharolyticus.*
      2. Hydrogen sulfide formed. Deep agar colonies become black.
        20. *Micrococcus niger.*
  II. No gas formed from nitrogenous media.
    A. Acid from glucose.
      1. Acid from lactose.
        21. *Micrococcus grigoroffi.*
      2. No acid from lactose.
        22. *Micrococcus anaerobius.*

1. **Micrococcus luteus** (Schroeter) Cohn. (*Bacteridium luteum* Schroeter, Beitr. z. Biol. d. Pflan., *1*, Heft 2, 1872, 119; Cohn, *ibid.*, 153.) From Latin, *luteus* golden-yellow.

Spheres: 1.0 to 1.2 microns, occurring in pairs and fours. Non-motile. Gram-positive.

Gelatin colonies: Yellowish-white to yellow, raised, with undulate margin.

Gelatin stab: No liquefaction.

Agar colonies: Small, yellowish, glistening, raised.

Agar slant: Citron-yellow, smooth.

Broth: Clear, with yellowish sediment.

Litmus milk: Usually slightly acid, not coagulated.

Potato: Thin, glistening, citron-yellow growth.

Indole not formed.

Nitrites not produced from nitrates.

Acid from glucose, sucrose and mannitol. No acid from lactose.

Starch not hydrolyzed.

Ammonia produced from peptone.

Utilizes $NH_4H_2PO_4$ as a source of nitrogen.

Saprophytic.

Aerobic.

Optimum temperature 25°C.

Source: Isolated by Schroeter from dust contaminations on cooked potato.

Habitat: Found in skim milk and dairy products, and on dust particles.

2. **Micrococcus ureae** Cohn. (Cohn, Beitr. z. Biol. d. Pflanzen, *1*, Heft 2, 1872, 158; not *Micrococcus ureae* Flügge, Die Mikroorganismen, 2 Aufl., 1886, 169; *Merista ureae* Prazmowski, Biol. Cent., *8*, 1888, 301; *Streptococcus ureae* Trevisan, I generi e le specie delle Bat-

teriacee, Milan, 1889, 31; *Urococcus ureae* Beijerinck, Cent. f. Bakt., II Abt., 7, 1901, 52; *Albococcus ureae* Kligler, Jour. Infect. Dis., *12*, 1943, 442; *Staphylococcus ureae* Holland, Jour. Bact., *5*, 1920, 225.) From Greek, *urum*, urine; M. L., *urea*, urea.

See *Micrococcus liquefaciens* Migula in the appendix for references to the gelatin-liquefying form of the species.

Spheres: 0.8 to 1.0 micron, occurring singly, in pairs and in clumps. Never in chains. Non-motile. Gram-variable.

Gelatin colonies: Small, white, translucent, slimy, becoming fissured.

Gelatin stab: Slight, white growth. Very slow or no liquefaction.

Agar colonies: White, slightly raised.

Agar slant: Grayish-white, raised, glistening, butyrous.

Broth: Turbid, with viscid sediment.

Litmus milk: Slightly alkaline; litmus slowly reduced.

Milk: Acid.

Potato: Slight, grayish to pale olive growth.

Indole not formed.

Nitrites not produced from nitrates.

Urea fermented to ammonium carbonate.

Acid produced from glucose, lactose, sucrose and mannitol.

Starch not hydrolyzed.

Ammonium salts are utilized.

Ammonia produced from peptone.

Saprophytic.

Aerobic.

Optimum temperature 25°C.

Source: Isolated from fermenting urine.

Habitat: Found in stale urine and in soil containing urine.

3. **Micrococcus freudenreichii** Guillebeau. (Landwirtsch. Jahrb. d. Schweiz, *5*, 1891, 135.) Named for E. v. Freudenreich, Swiss bacteriologist.

Synonyms: *Micrococcus acidi lactis* Krueger, Cent. f. Bakt., 7, 1890, 464 (*Micrococcus acidi lactis liquefaciens* Eisenberg, Bakt. Diag., 3 Aufl., 1891, 409; *Micrococcus acidi lactici liquefaciens* Sternberg, Man. of Bact., 1893, 601; *Micrococcus acidilactis* Migula, Syst. d. Bakt., *2*, 1900, 112; *Micrococcus acidificans* Migula, *ibid.*); *Micrococcus lactis viscosus* Sternberg, Man. of Bact., 1893, 604; *Micrococcus amarifaciens* Migula, Syst. d. Bakt., *2*, 1900, 100; *Coccus lactis viscosi* Gruber, Cent. f. Bakt., II Abt., *9*, 1902, 790 (*Micrococcus lactis viscosi* Löhnis, Cent. f. Bakt., II Abt., *18*, 1907, 144); *Micrococcus lactis albidus* Conn, Esten and Stocking, Storrs Agr. Exp. Sta. 18th Ann. Rept., 1906, 91.

Spheres: 2.0 microns in diameter, occuring singly and in clumps, rarely in short chains. Non-motile. Gram-positive.

Milk gelatin colonies: Small, white, opaque.

Milk gelatin stab: Infundibuliform liquefaction.

Agar colonies: White, slimy.

Agar streak: White, smooth.

Broth: Turbid, with white sediment.

Litmus milk: Acid; coagulated; peptonized.

Potato: Moderate white to yellow streak.

Indole not formed.

Nitrites not produced from nitrates.

Starch not hydrolyzed.

Ammonia produced from peptone.

Does not utilize urea as a source of nitrogen.

Acid from glucose, lactose and sucrose. Some strains form acid from mannitol; others from glycerol.

Saprophytic.

Aerobic.

Optimum temperature 20°C.

Habitat: Milk and dairy utensils.

4. **Micrococcus flavus** Trevisan. (*Micrococcus flavus liquefaciens* Flügge, Die Mikroorganismen, 2 Aufl., 1886, 174; Trevisan, I generi e le specie delle Batteriacee, Milan, 1889, 34; *Micrococcus flavus-liquefaciens* Chester, Man. Determ. Bact., 1901, 99.) From Latin, *flavus*, yellow.

Spheres: 0.8 to 0.9 micron, occurring

singly, in clumps, and occasionally in fours. Occasionally cultures are found that are motile with a single flagellum. Otherwise non-motile. Gram-variable.

Gelatin colonies: Small, circular, yellowish to yellowish-brown, somewhat serrate margin, granulated, sharply contoured.

Gelatin stab: Yellow, wrinkled surface growth with slow, crateriform liquefaction.

Agar colonies: Small, pale yellowish, homogeneous, entire.

Agar slant: Canary-yellow, somewhat dry, wrinkled, raised, entire.

Broth: Turbid with yellowish ring and sediment.

Litmus milk: Slightly acid, soft coagulum formed, with slight reduction; slowly peptonized.

Potato: Slight, canary-yellow growth.

Indole is not formed.

Nitrites not produced from nitrates.

Starch not hydrolyzed.

Acid is generally formed from glucose and lactose. Sucrose, glycerol and mannitol generally not fermented.

Ammonium salts are utilized.

Ammonia produced from peptone.

Non-pathogenic.

Aerobic.

Optimum temperature 25°C.

Source: Original source not given.

Habitat: Found in skin gland secretions, milk, dairy products, and dairy utensils.

5. Micrococcus candidus Cohn. (Cohn, Beitr. z. Biol. d. Pflanzen, *1*, Heft 2, 1872, 160; *Staphylococcus candidus* Holland, Jour. Bact., *5*, 1920, 223.) From Latin *candidus*, shining white.

Spheres: 0.5 to 0.7 micron, occurring singly. Non-motile. Gram-positive.

Gelatin colonies: White, granular, with irregular or entire margin.

Gelatin stab: White surface growth. Filiform. No liquefaction.

Agar colonies: Punctiform, white, smooth, entire, iridescent.

Agar slant: Smooth, white, glistening, iridescent.

Broth: Turbid, with pellicle.

Litmus milk: Slightly acid; not coagulated.

Potato: Thick, porcelain white, glistening.

Indole not produced.

Nitrites not produced from nitrates.

Starch not hydrolyzed.

Ammonia produced from peptone.

Ammonium salts not utilized.

Acid from glucose, sucrose, lactose and glycerol.

Non-pathogenic.

Aerobic.

Optimum temperature 25°C.

Source: Originally appeared as white colonies on cooked potato exposed to dust contaminations.

Habitat: Found in skin secretions, milk and dairy products.

6. Micrococcus conglomeratus Migula. (Citronengelber Diplococcus, Bumm, Der Mikroorganismen der gonorrhoischen Schleimhauterkrankungen, 1 Aufl., 1885, 17; *Micrococcus citreus conglomeratus* Flügge, Die Mikroorganismen, 2 Aufl., 1886, 182; *Diplococcus citreus conglomeratus* Bumm, *ibid.*, 2 Aufl., 1887; *Neisseria citrea* Trevisan, I generi e le specie delle Batteriacee, Milan, 1889, 32; *Merismopedia citreus conglomeratus* Dyar, Ann, N. Y. Acad. Sci., *8*, 1895, 352; Migula, Syst. d. Bakt., *2*, 1900, 146; not *Micrococcus conglomeratus* Weichselbaum, 1887, see Trevisan, *loc. cit.*, 33; *Micrococcus citreus* Winslow and Winslow, Systematic Relationships of the Coccaceae, 1908, 218.) From Latin, *conglomeratus*, rolled together, crowded.

Spheres: 0.8 to 1.2 microns, occurring singly, in pairs, in fours, and in large clumps. Non-motile. Gram-variable.

Gelatin colonies: Small, circular, yellow with radiate margin.

Gelatin stab: Slow crateriform liquefaction.

Agar colonies: Luxuriant, moist, sulfur yellow.

Agar slant: Light yellow, plumose, slightly rugose, somewhat dull, raised center and transparent margin.

Broth: Turbid, with light orange ring and sediment.

Milk: Generally acid but not sufficient to curdle.

Potato: No growth.

Indole not formed.

Nitrites produced from nitrates.

Blood not hemolyzed.

Starch not hydrolyzed.

Acid from glucose and lactose generally, sometimes from sucrose. Mannitol and glycerol generally not fermented.

Ammonia produced from peptone.

Utilizes $NH_4H_2PO_4$ as a source of nitrogen.

Resistant to drying and heat.

Non-pathogenic.

Aerobic.

Optimum temperature 25°C.

Source: Found in gonorrhoeal pus and dust.

Habitat: Infections, milk, dairy products, dairy utensils, water, common.

7. **Micrococcus varians** Migula. (*Merismopedia flava varians* Dyar, Ann. N. Y. Acad. Sci., *8*, 1895, 346; Migula, Syst. d. Bakt., *2*, 1900, 135; *Merismopedia flava-varians* Chester, Man. Determ. Bact., 1901, 103; *Micrococcus lactis varians* Conn, Esten and Stocking, Storrs Agr. Exp. Sta. Rept. for 1906, 121.) From Latin, *varians* varying.

Spheres: 0.8 to 1.0 micron, occurring singly, in pairs and in fours. Occasionally cultures are found that are motile with a single flagellum. Otherwise non-motile. Gram-variable.

Gelatin colonies: Small, circular, whitish to yellow, capitate, moruloid.

Gelatin stab: Scant growth. No liquefaction.

Agar colonies: Small, yellow, raised, glistening.

Agar slant: Plumose, yellow, variegated.

Broth: Turbid, with yellow, granular sediment.

Litmus milk: Acid; coagulated on boiling.

Potato: Raised, dry, bright-yellow, glistening.

Indole not formed.

Nitrites produced from nitrates.

Acid from glucose, lactose, sucrose, raffinose and frequently from glycerol and mannitol. No acid from salicin or inulin.

Starch not hydrolyzed.

Ammonia produced from peptone.

Utilizes $NH_4H_2PO_4$ as a source of nitrogen.

Saprophytic.

Aerobic.

Optimum temperature 25°C.

Source: Original strains found in a contaminated jar of sterilized milk.

Habitat: Has been found in body secretions, dairy products, dairy utensils, dust and water, including sea water.

8. **Micrococcus caseolyticus** Evans. (Evans, Jour. Inf. Dis., *18*, 1916, 455; *Micrococcus casei* Hucker, N. Y. Agr. Exp. Sta. Tech. Bull. 102, 1924, 17; Probably *Micrococcus casei* Holland, Jour. Bact., *5*, 1920, 223.)

Identical in part with *Micrococcus casei acidoproteolyticus I* and *II* Gorini, Rev. Gén. du Lait, *8*, 1910, 337; *Tetracoccus liquefaciens* Orla-Jensen, The Lactic Acid Bacteria, 1919, 80 (*Micrococcus casei liquefaciens* Orla-Jensen, Doktordisputats, 1904; *Tetracoccus casei liquefaciens* Orla-Jensen, The Lactic Acid Bacteria, 1919, 80; *Micrococcus liquefaciens* Holland, Jour. Bact., *5*, 1920, 224. Also see references under *Streptococcus liquefaciens*.) From Latin, *caseus*, cheese, casein; and Greek, *lyticus*, able to dissolve; M. L., dissolving, digesting.

Spheres, variable in size, occurring in clumps. Non-motile. Gram-positive.

Gelatin stab: Liquefaction generally

begins after first day and continues rapidly.

Agar colonies: Yellow to orange (Evans, *loc. cit.*), pearly white (Hucker, *loc. cit.*).

Agar stroke: Yellow to orange (Evans, *loc. cit.*), pearly white (Hucker, *loc. cit.*), luxuriant growth.

Broth: Generally grows with smooth turbidity although certain strains give heavy precipitate with clear supernatant fluid.

Litmus milk: Acid, peptonized. Whey generally clear.

Potato: Scanty white growth. Certain strains may show yellow pigment.

Indole not formed.

Nitrites usually produced from nitrates.

Acid from glucose, lactose, maltose, mannitol and glycerol. No action on raffinose.

Forms dextrorotary lactic acid (Orla-Jensen, 1919, *loc. cit.*).

Asparagin and urea decomposed by some strains.

Utilizes $NH_4H_2PO_4$ as a source of nitrogen.

Optimum temperature 22°C.

Aerobic.

Saprophytic.

Source: Eight cultures from bovine udder.

Habitat: Milk and dairy products, especially cheese, dairy utensils.

9a. **Micrococcus pyogenes** var. **aureus** (Rosenbach) Zopf. (*Staphylococcus pyogenes aureus* Rosenbach, Mikroorganismen bei den Wundinfectionskrankheiten des Menschen, Wiesbaden, 1884, 19; *Staphylococcus aureus* Rosenbach, *ibid.*, 27; *Micrococcus pyogenes* var. *aureus* Zopf, Die Spaltpilze, 3 Aufl., 1885, 56; *Micrococcus aureus* Zopf, *ibid.*, 57; *Micrococcus pyogenes* Lehmann and Neumann, Bakt. Diag., 1 Aufl., *2*, 1896, 165; *Aurococcus aureus* Winslow and Rogers, Jour. Inf. Dis., *3*, 1906, 554; *Micrococcus lactis varians* Conn, Esten and Stocking, Storrs Agr. Exp. Sta. Rept. for 1906, 121; *Staphylococcus pyogenes* Andrewes and Gordon, Rept. (35th) Med. Officer Local Govt. Board, London, 1907, 549; (*Tetracoccus*) *Micrococcus pyogenes aureus* Orla-Jensen, The Lactic Acid Bacteria, 1919, 81; *Staphylococcus pyogenes-aureus* Holland, Jour. Bact., *5*, 1920, 225.) From Greek, *pyon*, pus; M. L.,-*genes*, producing. From Latin, *aureus*, golden.

Spheres: 0.8 to 1.0 micron, occurring singly, in pairs, in short chains, and in irregular clumps. Non-motile. Gram-positive.

Gelatin stab: Saccate liquefaction with yellowish pellicle and yellow to orange sediment.

Agar colonies: Circular, smooth, yellowish to orange, glistening, butyrous, entire.

Agar slant: Abundant, opaque, smooth, flat, moist, yellowish to orange.

Broth: Turbid with yellowish ring and sediment, becoming clear.

Litmus milk: Acid; coagulated.

Potato: Abundant, orange, glistening.

Indole not formed.

Nitrites produced from nitrates.

Acid from glucose, lactose, sucrose, mannitol and glycerol, but not from raffinose, salicin or inulin.

Forms inactive or levorotary lactic acid (Orla-Jensen, *loc. cit.*).

Slight H_2S formation.

Starch not hydrolyzed.

Does not utilize $NH_4H_2PO_4$, as a source of nitrogen.

Ammonia produced from peptone.

Pathogenic. Individual strains vary in their ability to produce hemolysin, coagulase and other metabolic products.

Certain strains, under favorable conditions, produce not only exotoxins (hematoxin, dermatoxin, lethal toxin, etc.) but also a potent enterotoxin which is a significant cause of food poisoning (Dolman and Wilson, Jour. Immunology, *35*, 1938, 13).

Aerobic, facultative.

Optimum temperature 37°C.

Source: Isolated from pus in wounds.

Habitat: Skin and mucous membranes. The cause of boils, abscesses, furuncles suppuration in wounds, etc.

9b. **Micrococcus pyogenes** var. **albus** (Rosenbach) Schroeter. (*Staphylococcus pyogenes albus* Rosenbach, Mikroorganismen bei den Wundinfektionskrankheiten des Menschen, Wiesbaden, 1884, 2; *Staphylococcus albus* Rosenbach, *ibid.*, 27; *Micrococcus pyogenes* var. *albus* Schroeter, in Cohn, Kryptog. Flora v. Schlesien, *3*, 1, 1886, 147; *Micrococcus pyogenes* Migula, Syst. d. Bakt., *2*, 1900, 87; *Albococcus pyogenes* Winslow and Rogers, Jour. Inf. Dis., *3*, 1906, 544; *Micrococcus albus* Buchanan, Veterinary Bacteriology 1911, 196; (*Tetracoccus*) *Micrococus pyogenes albus* Orla-Jensen, The Lactic Acid Bacteria, 1919, 81; *Staphylococcus pyogenes-albus* Holland, Jour. Bact., *5*, 1920, 225.) From Latin, *albus*, white.

Spheres: 0.6 to 0.8 micron, occurring singly, in pairs and in irregular groups. Non-motile. Gram-positive.

Gelatin stab: Saccate liquefaction with heavy white sediment.

Agar colonies: Circular, white, smooth, glistening, entire.

Ten per cent evaporated milk agar: Growth at 20°C frequently orange (Chapman, Jour. Bact., *45*, 1943, 405).

Agar slant: Abundant, white, smooth, glistening.

Broth: Turbid, with delicate pellicle and white sediment.

Litmus milk: Acid; coagulated. Little or no visible peptonization.

Potato: Thick, smooth, white, glistening.

Indole not formed.

Nitrites produced from nitrates.

Hydrogen sulfide is formed.

Acid formed from glucose, lactose, sucrose, glycerol and mannitol, but not from raffinose, salicin and inulin.

Forms inactive or levorotary lactic acid (Orla-Jensen, *loc. cit.*).

Starch not hydrolyzed.

Ammonia produced from peptone.

Does not utilize $NH_4H_2PO_4$ as a source of nitrogen.

Pathogenic. Production of toxins, coagulase and hemolysin as in *Micrococcus aureus*.

Aerobic, facultative.

Optimum temperature 37°C.

Source: Originally isolated from pus.

Habitat: Skin and mucous membranes. Occurs in wounds, boils, abscesses, etc.

10. **Micrococcus citreus** Migula. (*Staphylococcus pyogenes citreus* Passet, Aetiologie der eiterigen phlegmone des Menschen, Berlin, 1885, 9; *Micrococcus pyogenes citreus* Schroeter, in Cohn, Kryptog. Flora v. Schlesien, *3*, 1, 1886, 147; Migula, Syst. d. Bakt., *2*, 1900, 147; *Staphylococcus citreus* Bergey et al., Manual, 1st ed., 1923, 55.) From Latin, *citreus*, of or relating to the citrus tree; M. L., lemon yellow.

Spheres: 0.9 micron, occurring singly. Gram-positive.

Gelatin colonies: Circular, pale yellow, granular, entire, liquefying in 6 days.

Gelatin stab: Lemon yellow surface growth sinking into the medium. Grayish-white growth in stab. Complete liquefaction in 43 days.

Agar colonies: Small, yellow, smooth, entire.

Agar slant: Broad, lemon yellow, glistening, elastic.

Broth: Turbid, with yellow sediment and pellicle.

Litmus milk: Acid, with slow coagulation.

Potato: Thin, grayish streak, becoming citron yellow.

Indole not formed.

Nitrites produced from nitrates.

Starch not hydrolyzed.

Acid from glucose, lactose, sucrose, raffinose, inulin, salicin, glycerol and mannitol.

Does not utilize $NH_4H_2PO_4$ as a source of nitrogen.

Ammonia produced from peptone.

Aerobic, facultative.

Pathogenic.

Optimum temperature 37°C.

Source: Originally isolated from pus.

Habitat: Skin and mucous membranes of vertebrates.

11. **Micrococcus aurantiacus** (Schroeter) Cohn. (*Bacteridium aurantiacum* Schroeter, Beitr. z. Biol., *1*, Heft 2, 1872, 126; Cohn, Beitr. z. Biol., *1*, Heft 2, 1872, 154; *Pediococcus aurantiacus* De Toni and Trevisan, in Saccardo, Sylloge Fungorum, *8*, 1889, 1051; *Micrococcus aurantiacus-sorghi* Bruyning, Arch. Néer. Sci. Exact. et Nat., *1*, 1898, 297; *Streptococcus aurantiacus* Chester, Man. Determ. Bact., 1901, 69; *Aurococcus aurantiacus* Winslow and Winslow, Systematic Relationships of the Coccaceae, 1908, 186; *Sarcina aurantiaca* Holland, Jour. Bact., *5*, 1920, 225 (not *Sarcina aurantiaca* Flügge, Die Mikroorganismen, 2 Aufl., 1886, 180); *Staphylococcus aurantiacus* Holland, *ibid.*) From Latin, *aurum*, gold; M. L., *aurantium*, the orange; M.L., *aurantiacus*, orange-colored.

Spheres: Slightly ellipsoidal, 1.3 to 1.5 microns, occurring singly, in short chains and in small clumps. Non-motile. Gram-positive.

Gelatin colonies: Circular to oval, smooth, glistening with yellow to orange center.

Gelatin stab: Yellow surface growth. No liquefaction.

Agar colonies: Circular, smooth, glistening, yellow to orange, entire.

Agar slant: Buff to scant orange-yellow, beaded growth, raised, glistening.

Broth: Turbid, with pellicle.

Litmus milk: Faintly acid, no coagulation.

Potato: Slimy, yellow growth. Pigment is insoluble in alcohol and ether.

Indole not produced.

Nitrites generally produced from nitrates.

Slight acidity from glucose, fructose, sucrose, lactose and mannitol. No acid from raffinose, salicin, inulin.

Starch not hydrolyzed.

Ammonia produced from peptone.

No growth in ammonium media.

May be pathogenic.

Optimum temperature 25°C.

Aerobic.

Source: First isolated from colonies that grew on boiled egg exposed to dust contamination.

Habitat: Usually isolated from infections but also found in milk, cheese and dust.

NOTE: *Albococcus epidermidis* (var. A) Kligler (Jour. Infect. Dis., *12*, 1913, 444) which was based on a white culture received from Kral under the name *Micrococcus aurantiacus* was apparently a white strain of this organism as it grew luxuriantly on ordinary agar.

12. **Micrococcus epidermidis** (Winslow and Winslow) Hucker. (*Staphylococcus epidermidis albus* Welch, Amer. Jour. of Med. Sci., Phila., N. S., *102*, 1891, 441; *Micrococcus epidermidis albus* Randolph, Jour. Amer. Med. Assoc., *31*, 1898, 706; *Albococcus epidermidis* Winslow and Winslow, Syst. Relationships Coccaceae, New York, 1908, 201; *Staphylococcus epidermidis* Evans, Jour. Inf. Dis., *15*, 1916, 449; Hucker, N. Y. Agr. Exp. Sta. Tech. Bull. 102, 1924, 21.) From Greek, *epidermis*, the outer skin.

Spheres: 0.5 to 0.6 micron, occurring singly, in pairs and in irregular groups. Non-motile. Gram-positive.

Gelatin stab: White surface growth with slow saccate liquefaction.

Agar colonies: Rather scant, white, translucent.

Broth: Turbid, with white ring and sediment.

Litmus milk: Acid.

Potato: Limited growth, white.

Indole not formed.

Nitrites are produced from nitrates.

Usually does not utilize $NH_4H_2PO_4$ as a source of nitrogen.

Acid formed from glucose, fructose, maltose, lactose and sucrose, but not from mannitol, raffinose, salicin or inulin.

Usually fails to hemolyze blood. No coagulase produced.

Parasitic rather than pathogenic.

Aerobic, facultative.

Optimumtemperature 37°C.

Source: Originally isolated from small stitch abscesses and other skin wounds.

Habitat: Skin and mucous membranes.

13. **Micrococcus roseus** Flügge. (Rosafarbiger Diplococcus, Bumm, Der Mikroorganismen der gonorrhoischen Schleimhauterkrankungen, 1 Aufl., 1885, 25; Flügge, Die Mikroorganismen, 2 Aufl., 1886, 183; *Neisseria rosea* Trevisan, I generi e le specie delle Batteriacee, Milan, 1889, 32; *Diplococcus roseus* Eisenberg, Bakt. Diag., 3 Aufl., 1891, 12; *Merismopedia rosea* Dyar, Ann. N. Y. Acad. Sci., *8*, 1895, 354; *Rhodococcus roseus* Winslow and Rogers, Jour. Inf. Dis., *3*, 1906, 545.) From Latin, *roseus*, rose-colored.

Spheres: 1.0 to 1.5 microns, occurring singly and in pairs. Non-motile. Gram-variable.

Gelatin colonies: Rose surface growth usually with slow liquefaction.

Agar colonies: Circular, entire, rose-red surface colonies.

Agar slant: Thick, rose-red, smooth, glistening streak.

Broth: Slightly turbid with rose-colored sediment.

Litmus milk: Unchanged to alkaline, usually reddish sediment after 14 days.

Usually produce nitrites from nitrates.

Potato: Raised, rose-red, smooth, glistening.

Starch not hydrolyzed.

Acid from glycerol and mannitol.

Utilizes $NH_4H_2PO_4$ as a source of nitrogen.

Saprophytic.

Aerobic.

Optimum temperature 25°C.

Source: Dust contamination.

Habitat: Widespread, as it occurs in dust.

14. **Micrococcus cinnabareus** Flügge. (Flügge, Die Mikroorganismen, 2 Aufl., 1886, 174; *Rhodococcus cinnabareus* Winslow and Rogers, Jour. Inf. Dis., *3*, 1906, 545.) From M. L., cinnabar-colored.

Spheres: 1.0 micron, occurring singly and in pairs. Non-motile. Gram-variable.

Gelatin colonies: Small, circular, bright red, becoming cinnabar red.

Gelatin stab: Thick, raised, rose to cinnabar red growth on surface. No liquefaction. White colonies along stab.

Agar slant: A carmine-red streak. Slow growth.

Broth: Turbid.

Litmus milk: Slightly alkaline to slightly acid.

Potato: Slowly developing vermillion red streak.

Small amount of acid from test sugars.

Indole not formed.

Does not utilize $NH_4H_2PO_4$ as a source of nitrogen.

Nitrites produced from nitrates.

Starch not hydrolyzed.

Saprophytic.

Aerobic.

Optimum temperature 25°C.

Source: Found as contamination of cultures.

Habitat: Usually found as a dust contamination.

15. **Micrococcus rubens** Migula. (*Micrococcus tetragenus ruber* Bujwid, in Schneider, Arb. bakt. Inst. Karlsruhe, *1*, Heft 2, 1894, 215; Migula, Syst. d. Bakt., *2*, 1900, 177; *Micrococcus ruber* and *Rhodococcus ruber* Holland, Jour. Bact., *6*, 1920, 224; *Micrococcus roseofulvus* Hucker, N. Y. S. Agr. Exp. Sta. Tech. Bull. 135, 1928, 27; not *Micrococcus roseofulvus* Lehmann and Neumann, Bakt. Diag., 1 Aufl., *2*, 1896, 177 and 439; *Rhodococcus roseofulvus* Pribram, Klassifikation der Schizomyceten, 1933, 44). From Latin, *rubens*, ruddy.

The following description is taken from Migula (*loc. cit.*) and from Hucker (*loc. cit.*) supplemented from unpublished notes of the latter. Also see Breed (Jour. Bact., *45*, 1943, 455).

Spheres: 1.3 to 4.0 microns, average size 2.1 microns, occurring in fours and

in irregular masses, generally not singly or in pairs. Non-motile. Gram-negative to Gram-variable

Gelatin colonies: After several days, small, pink or flesh-colored, shiny, butyrous, 0.5 to several mm. in diameter. Smaller colonies have regular edges; larger colonies have lobate edges.

Gelatin streak: Thick, shiny, flesh-colored to carmine-red growth, generally spreading.

Gelatin stab: Scant, whitish growth along line of stab; surface growth flesh-red. No liquefaction after several weeks, but a slight softening of the medium underneath the growth.

Agar slant: Luxuriant, thick, spreading, slimy, flesh-colored growth.

Broth: Bright red, slimy sediment. No pellicle.

Milk: Generally acid curd followed by slight peptonization.

Nitrites produced from nitrates.

Acid from glucose, sucrose, mannitol and glycerol. No action on lactose or starch.

Pigment soluble in ether, benzol, carbon bisulfide, chloroform and alcohol. Not soluble in water (Schneider, *loc. cit.*).

Saprophytic.

Grows well at 26° to 37°C.

Aerobic.

Source: Original culture isolated by Bujwid in Bern, Switzerland and sent to Migula at Karlsruhe, Germany.

Habitat: Unknown.

16. **Micrococcus rhodochrous** (Zopf) Migula. (*Rhodococcus rhodochrous* Zopf, Berichte d. deutsch. bot. Gesellsch., *9*, 1891, 22; Migula, Syst. d. Bakt., *2*, 1900, 162.) From Greek, *rhodum*, rose; *chros*, color.

Spheres: 0.5 to 1.0 micron, occurring singly. Non-motile. Gram-variable.

Gelatin colonies: Small, circular, glistening, raised, entire, dark, reddish-brown.

Gelatin stab: Dark, carmine-red, dry surface growth. Slight growth in stab. No liquefaction.

Agar slant: Carmine-red streak, becoming brick-red in color.

Broth: Thick rose-red pellicle with red, flocculent sediment.

Litmus milk: Slightly alkaline.

Potato: Carmine-red streak.

Does not ferment glycerol and mannitol.

Aerobic.

Saprophytic.

Optimum temperature 25°C.

Habitat: Water.

17. **Micrococcus agilis** Ali-Cohen. (Ali-Cohen, Cent. f. Bakt., *6*, 1889, 36; *Planosarcina agilis* Migula, in Engler and Prantl, Die natürl. Pflanzenfam., *1*, 1a, 1895, 20; *Micrococcus agilis ruber* Peppler, Cent. f. Bakt., I Abt., *29*, 1901, 352; *Planococcus agilis* Chester, Man. Determ. Bact., 1901, 115; *Rhodococcus agilis* Winslow and Rogers, Jour. Inf. Dis., *3*, 1906, 545; *Sarcina agilis* Enderlein, Sitzber. Gesell. Naturf. Freunde Berlin, 1930, 182; not *Sarcina agilis* Matzuschita, Zeit. f. Hyg., *35*, 1900, 496; not *Sarcina agilis* Saito, Jour. Coll. Sci. Imp. Univ. Tokyo, *23*, 1908, .) From Latin, *agilis*, agile.

Spheres, 1.0 micron, occurring singly, in pairs and in fours. Motile by means of one or two flagella. Gram-variable.

Gelatin colonies: Small, gray, becoming distinctly rose-colored.

Gelatin stab: Thin, whitish growth in stab. On surface thick, rose-red, glistening growth. Generally no liquefaction.

Agar slant: Glistening, dark rose-red, lobed, much variation in color.

Broth: Slightly turbid, with slight, rose-colored ring and pink sediment.

Litmus milk: Slightly acid, pink sediment.

Potato: Slow growth as small, rose-colored colonies.

Loeffler's blood serum: Pink, spread-

ing, shiny, abundant. Slow liquefaction.

Indole not formed.

Nitrites produced (trace).

Ammonia formed (trace).

Does not utilize $NH_4H_2PO_4$ as source of nitrogen.

Acid from glucose, sucrose, inulin, glycerol and mannitol. No acid from raffinose.

Aerobic.

Saprophytic.

Optimum temperature 25°C.

Source: Isolated from water.

Habitat: Water, sea water, on sea fish.

*18. **Micrococcus aerogenes** (Schottmüller) Bergey et al. (*Staphylococcus aerogenes* Schottmüller, Cent. f. Bakt., I Abt., Orig., *64*, 1912, 270; Bergey et al., Manual, 1st ed., 1923, 70; not *Micrococcus aerogenes* Miller, Deutsch. med. Wchnschr., *12*, 1886, 119.) From Greek, forming air or gas.

Description according to Prévot, Ann. Sci. Nat., Sér. Bot. et Zool., *15*, 1933, 212.

Spheres: 0.6 to 0.8 micron, occurring in clusters, sometimes in pairs or short chains. Gram-positive.

Gelatin: No liquefaction.

Deep agar colonies: Small, lenticular, nearly spherical, yellowish white. Some gas bubbles produced, not fetid.

Blood agar colonies: Very small, grayish. No true hemolysis, but a narrow clear zone is formed.

Serum agar: Colonies lenticular. Gas not fetid.

Neutral red serum agar: Colonies lenticular. Gas produced. Neutral red changed to greenish yellow.

Glucose broth with blood: Turbid. Gas produced. Hydrogen sulfide not produced. Slight hemolysis.

Glucose serum broth: Turbid. Gas produced.

Peptone water with serum: Gas. Indole produced.

Milk: Growth feeble. Neither acid nor coagulated.

Proteins not attacked.

Glucose and fructose attacked slightly by two out of three strains.

Does not plasmolyse readily.

Neutral red broth: Changed to yellowish green.

Nitrites not produced from nitrates.

Optimum pH 6.5 to 8.0.

Optimum temperature 37°C.

Pathogenic.

Strict anaerobe.

Distinctive character: Fermentation of glucose and gas production from peptones.

Source: Isolated (Schottmüller) from cases of puerperal fever. Three strains from infected tonsils studied by Prévot.

Habitat: Natural cavities, especially the tonsils and female genital organs.

19. **Micrococcus asaccharolyticus** (Distaso) *comb. nov.* (*Staphylococcus asaccharolyticus* Distaso, Cent. f. Bakt., I Abt., Orig., *62*, 1912, 445.) From Greek, not dissolving sugar.

Description according to Prévot, Ann. Sci. Nat., Sér. Bot., *15*, 1933, 211.

Large spheres: 1.0 to 1.2 microns, occurring in very large clusters, also in pairs and short chains. Gram-positive.

Gelatin: At 37°C, growth resembles tufts of cotton which precipitate. No liquefaction.

Deep agar colonies: Very delicate, pin-point, transparent. A few bubbles of gas produced.

Broth: Turbid. Growth settles at the bottom of the tube as a sort of viscous zooglea. Unpleasant odor produced.

Peptone water: Turbid. Indole produced.

Milk: Feebly acidified, but not coagulated.

Egg white not attacked.

Carbohydrates not attacked.

Strict anaerobe.

* Anaerobic section revised by Dr. Ivan C. Hall, New York, N. Y.

Distinctive characters: Large size; unpleasant odor; production of indole; production of gas.

Source: Isolated from the large intestine of a man with intestinal intoxication.

Habitat: Intestine. Not common.

NOTE: Weinberg, Nativelle and Prévot (Les Microbes Anaérobies, 1937, 1023) regard *Micrococcus indolicus* Christiansen (Ac. Pat. Micr. Scand., *18*, 1934, 42) as a variety of this species giving it the name *Staphylococcus asaccharolyticus* var. *indolicus*. This variety differs from the species by forming opaque lens-shaped colonies and by a more abundant production of gas from peptone.

20. **Micrococcus niger** Hall. (Jour. Bact., *20*, 1930, 409.) From Latin, *niger*, black.

Small spheres: 0.6 micron in diameter, occurring in irregular masses, occasionally in pairs. Gram-positive.

Gelatin: After 5 days a dark sediment is produced which gradually gets more and more intensely black. No liquefaction.

Deep agar colonies: Slow growth. At first very tiny, colorless, irregularly globular, smooth, dense. Small bubbles of gas sometimes produced. After several days colonies become brown, then black. If exposed to air, colonies fade to a dull gray. Medium not discolored.

Blood agar slant: After 4 or 5 days, minute, black colonies, round, smooth, glistening, 0.5 mm. in diameter. Non-hemolytic.

Broth: After 4 or 5 days uniform turbidity and slight production of gas which contains H_2S. Black sediment.

Coagulated serum: Minute, brown colonies appear on the 8th day. No liquefaction.

Milk: No change.

Brain medium: Turbid after 4 or 5 days at 37°C. Uniform gas production about the 6th day. Discoloration of the medium not marked.

No acid from carbohydrates. Black sediment produced.

Non-pathogenic for guinea-pigs and rabbits.

Optimum temperature 37°C. No growth below 30°C.

Strict anaerobe.

Distinctive characters: Formation of a water-insoluble, black pigment. Growth slow, visible after 2 to 4 days.

Source: Isolated from urine of an aged woman.

Habitat: Unknown.

21. **Micrococcus grigoroffi** Prévot. (*Micrococcus* A, Grigoroff, Thèse de Geneve, 1905; Prévot, Ann. Sci. Nat., Sér. Bot. et Zool., *15*, 1933, 219.) Named for Grigoroff, who first isolated this organism.

Small spheres: Average size 0.7 micron, occurring singly or in irregular masses. Gram-positive.

Gelatin: Colonies appear in four days. No liquefaction.

Deep agar colonies: After three days, round, lenticular, yellowish.

Glucose broth: Turbid after 2 days with whitish sediment. Neither gas nor fetid odor produced. The medium is acidified.

Milk: Good growth. Acid. Coagulation.

Acid from glucose, maltose, lactose, fructose and sorbitol.

One strain slightly pathogenic.

Optimum temperature 37°C.

Strict anaerobe.

Distinctive characters: This is the only anaerobic coccus growing in irregular masses that coagulates milk. Lactose is fermented.

Source: Five strains isolated from the appendix by Grigoroff. One strain isolated from an appendix by Prévot.

Habitat: Human digestive tract. Not common.

22. **Micrococcus anaerobius** (Hamm) *comb. nov.* (Anaerobic staphylococcus, Jungano, Compt. rend. Soc. Biol. Paris, *59*, 1907, 707; *Staphylococcus anaerobius*

Hamm, Die puerperale Wundinfektion, Berlin, 1912; not *Staphylococcus anaerobius* Heurlin, Bakt. Unters. d. Keimgehaltes im Genitalkanale d. fiebernden Wöchnerinnen, Helsingfors, 1910, 120.) From Greek, living without air.

Description according to Prévot, Ann. Sci. Nat., Sér. Bot., *15*, 1933, 209.

Small spheres: 0.5 to 0.6 micron, occurring in masses. Gram-positive.

Gelatin: No liquefaction.

Deep agar colonies: Lenticular, thick. No gas produced.

Broth: Turbid, later clearing. Sediment.

Glucose broth: Good growth. Neither acid nor gas produced.

Peptone water: No turbidity. No gas. Indole not produced.

Milk: Neither coagulated nor acidified.

Coagulated serum not attacked.

Egg white not attacked.

Carbohydrates not attacked by the strains of Jungano. Acid feebly produced from glucose and galactose by Prévot's strain.

Does not plasmolyse.

Temperature relations: Optimum 36° to 38°C. At 22°C growth slow, poor. No growth below 22°C. Killed in ten minutes at 80°C or in half an hour at 60°C.

Optimum pH 6.0 to 8.0.

Pathogenic for guinea-pigs and rabbits.

Strict anaerobe.

Distinctive characters: Neutral red broth remains unchanged. No gas produced.

Source: First isolated by Jungano from a case of cystitis. Found by Prévot in the pus from a suppurated tonsil.

Habitat: Urinary tract, urethra, intestine, buccal cavity and conjunctiva.

Appendix I*: The following genus is organized on a physiological basis. Because of this no attempt is made to fit it into the classification outline. A single species has been described.

Genus A. **Methanococcus** *Kluyver and van Niel.*

(Cent. f. Bakt., II Abt., *94*, 1936, 400.)

Spherical cells, occurring singly or in masses. Motility not observed. No endospores formed. Gram-variable. Chemo-heterotrophic, anaerobic, fermenting various organic compounds with the formation of methane. Saprophytes.

The type species is *Methanococcus mazei* Barker.

1. **Methanococcus mazei** Barker. (Pseudosarcina, Mazé, Compt. rend. Soc. Biol., Paris, *78*, 1915, 398; Barker, Arch. f. Mikrobiol., *7*, 1936, 430.) Named for Mazé, the French bacteriologist who first gave a clearly recognizable description of this type of methane organism.

Small spherical cells, occurring singly, in large, irregular masses, or in regular cysts of various sizes and forms. Nonmotile. Stains readily with erythrosine. Gram-variable.

Grows on calcium acetate enrichment media and ferments the acetate vigorously.

Grows slowly on agar containing 2 per cent clear mud extract.

Ferments acetic and butyric acids with production of methane in the presence of CO_2. Ethyl and butyl alcohols not attacked.

Does not utilize organic nitrogen.

Obligate anaerobe.

Grows best at 30° to 37°C.

Sources: Garden soil, black mud containing H_2S, feces of herbivorous animals.

Habitat: One of the most active methane-producing organisms found in nature.

* Appendixes I and II prepared by Prof. Robert S. Breed, New York State Experiment Station, Geneva, New York, December, 1943.

Appendix II: The following genus is recognized by workers in the brewing industry. It includes species that present characters intermediate between *Micrococcus*, *Sarcina* and *Streptococcus*. Many students prefer to regard these as species of *Micrococcus* (Hucker, N. Y. State Exper. Sta., Tech. Bul. 102, 1924, 5), of *Sarcina* (Macé, Traité pratique d. Bact., 4th ed., 1901, 460) or of *Streptococcus* (Shimwell, Sect. 670 in Hind, Brewing Science and Practice, New York, 1940). Others (Mees, Thesis, Delft, 1934) would include in the genus, the species described as *Tetracoccus* by Orla-Jensen (The Lactic Acid Bacteria, Copenhagen, 1919, 76).

Genus B. Pediococcus *Balcke.*

(Wchnschr. f. Brauerei, *1*, 1884, 257.)

Cocci occurring singly, in pairs and tetrads. Non-motile. No endospores. Gram-positive. Facultative anaerobes under favorable conditions, especially in acid media. Nitrites not produced from nitrates. Produce acidification and more or less clouding of wort and beer. Saprophytes.

The type species is *Pediococcus cerevisiae* Balcke.

1. **Pediococcus cerevisiae** Balcke. (Ferment No. 7, Pasteur, Études sur la bière, Paris, 1876, 4; *Sarcina* Balcke, Wchnschr. f. Brauerei, *1*, 1884, 183; *ibid.*, *1*, 1884, 257; *Merismopedia cerevisiae* Dyar, Ann. N. Y. Acad. Sci., *8*, 1895, 348; *Micrococcus cerevisiae* Migula, Syst. d. Bakt., *2*, 1900, 77; *Sarcina cerevisiae* Macé, Traité Pratique d. Bact., 4th ed., 1901, 460.) From Latin, *cerevisia*, beer.

Spheres: 1 to 1.3 microns, occurring singly, in pairs or tetrads. In acid media the latter prevail. Catalase negative. Non-motile. Gram-positive.

No growth in alkaline media.

Peptone, meat-extract gelatin: White becoming yellowish to yellowish brown. No liquefaction.

Wort gelatin with Ca-carbonate: White colonies, 2 to 3 mm; carbonate dissolved.

Meat extract gelatin stab: Growth along stab, white raised surface growth. No liquefaction.

Litmus milk: No growth.

Potato: Scanty growth.

Acid from glucose, fructose, maltose, sucrose.

Wort and beer: Slight to moderately turbid growth, strong development on bottom of the flask. Hop sensitive, but may develop in heavily hopped beers under special conditions.

Does not utilize urea.

Nitrites not produced from nitrates.

Facultative anaerobic.

Killed at 60°C. in 8 minutes. Optimum temperature: 25°C.

Source: Sarcina-sick beer.

Habitat: Wort, beer and beer yeast.

Additional species have been described from spoiled wort and beer which vary but slightly from the species first named and described by Balcke. These are listed below together with other species that have been placed in the genus.

Pediococcus acidilactici Lindner. (Lindner, Wchnschr. f. Brauerei, *3*, No. 23, 1887, see Cent. f. Bakt., *2*, 1887, 342; also see Die Sarcina-Organismen der Gährungsgewerbe, Lindner, Inaug. Diss., Berlin, 1888, 26, and Cent. f. Bakt., *4*, 1888, 429; *Micrococcus pseudocerevisiae* Migula, Syst. d. Bakt., *2*, 1900, 77; *Micrococcus acidi-lactici* Chester, Man. Determ. Bact., 1901, 88.) From spoiled mash.

Pediococcus albus Lindner. (Die Sarcina-Organismen der Gährungsgewerbe, Lindner, Inaug. Diss., Berlin, 1887, 39; see Cent. f. Bakt., *4*, 1888, 429; *Micrococcus pseudosarcina* Migula, Syst. d. Bakt., *2*, 1900, 92; *Micrococcus albus* Chester, Man. Determ. Bact., 1901, 97.) From spoiled beer.

Pediococcus damnosus Claussen.

(Compt. rend. Trav. Labor. de Carlsberg, *6*, 1906, 68; *Streptococcus damnosus* Shimwell and Kirkpatrick, Jour. Inst. Brewing, *45*, 1939, 137.) From clear, spoiled beer.

Pediococcus halophilus Mees. (Tetracoccus No. 1, Orla-Jensen, The Lactic Acid Bacteria, 1919, 77; Mees, Thesis, Delft, 1934, 94.) From anchovy pickle.

Pediococcus hennebergi Sollied. (Ztschr. Spiritusindus., *26*, 1903, 491.) From spoiled beer.

Pediococcus kochii Trevisan. (Mikrokokkus in Wundsecreten bei Menschen, Koch; Trevisan, I generi e le specie delle Batteriacee, Milan, 1889, 28.)

Pediococcus pentosaceus Mees. (Tetracoccus No. 2, Orla-Jensen, The Lactic Acid Bacteria, 1919, 78; Mees, Thesis, Delft, 1934, 94.) From yeast.

Pediococcus perniciosus Claussen (*loc. cit.*). From clouded, spoiled beer.

Pediococcus sarcinaeformis Reichard. (Ztschr. f. d. ges. Brauwesen, *17*, 1894, 257.) From spoiled beer.

Pediococcus urinae equi Mees. (Pferdeurinsarcina, von Huth, Alg. Ztg. f. Bierber. u. Malzfabr., 185, 968 and 981, 1885; *ibid.*, 1886, 141; Mees, Thesis, Delft, 1934, 95.) From horse urine.

Pediococcus violaceus (Kützing) Trevisan. (*Merismopedia violacea* Kützing; Trevisan, I generi e le specie delle Batteriacee, Milan, 1889, 28.)

Pedioplana haeckeli Wolff. (Cent. f. Bakt., II Abt., *18*, 1907, 9.) Motile. From rotting beets. Placed in a new genus *Pedioplana* Wolff (*loc. cit.*, 9).

Streptococcus damnosus var. *mucosus* Shimwell. (Shimwell, Sect. 670, Hind, Brewing Science and Practice, New York, 1940.) From ropy beer.

Appendix III*. The following species have been found in the literature and are listed here chiefly for their historical interest. Many are incompletely described, while many others are identical with previously described species. See Monographs by Winslow and Winslow, Systematic Relationships of the *Coccaceae*, 1908 and Hucker, N. Y. State Exper. Sta., Tech. Buls. Nos. 99–103. References are to Tech. Bul. 102.

Ascococcus cantabridgensis Hankin. (Quoted from Lehmann and Neumann, Bakt. Diag., 2 Aufl., *2*, 1899, 165.) Migula (Syst. d. Bakt., *2*, 1900, 195) reports he is unable to find further reference to this organism and we likewise are unable to trace it. From the human mouth.

Ascococcus gangrenosus Bevan. (Med. News, No. 1003, 1892, 375; Abst. in Cent. f. Bakt., *13*, 1893, 796.) From a gangrenous foot.

Ascococcus vibrans van Tieghem. (Bul. Soc. Bot. France, *27*, 1880, 150.) From water.

Aurococcus tropicus Chalmers and O'Farrell. (1913, quoted from Castellani and Chalmers, Man. Trop. Med., 3rd ed., 1919, 931.) Found in Ceylon in granulating ulcers of skin.

Coccus carduus Heurlin. (Bakt. Unters. d. Keimgehaltes im Genitalkanale d. fiebernden Wöchnerinnen. Helsingfors, 1910, 136.) Anaerobic. From genital canal.

Coccus caudatus Heurlin (*loc. cit.*, 84). From genital canal.

Coccus vaginalis Heurlin (*loc. cit.*, 79). From genital canal.

Galactococcus albus Guillebeau. (Landwirtsch. Jahrb. d. Schweiz, *4*, 1892, 27; Abst. in Cent. f. Bakt., *12*, 1892, 101.) From milk from an inflamed udder.

Galactococcus fulvus Guillebeau (*loc. cit.*). From milk from an inflamed udder.

Galactococcus versicolor Guillebeau (*loc. cit.*). From milk from an inflamed udder.

Gyrococcus flaccidifex Glaser and Chapman. (Science, *36*, 1912, 219.) Isolated from the gypsy moth, *Porthetria dispar*.

Jodococcus vaginatus Miller. (Miller,

* Prepared for Prof. G. J. Hucker by Mrs. Eleanore Heist Clise, New York State Experiment Station, Geneva, New York, March, 1943.

Mikroorganismen der Mundhöhle, 1889, 54; *Bacterium iogenum* Baumgartner, Ergebnisse d. ges. Zahnheilk., Heft 2, 1910, 729; Abst. in Cent. f. Bakt., I Abt., Ref., *48*, 1911, 621.) From the oral cavity.

Merismopedia aurantiaca Maggiora. (Giorn. Soc. Ital. d'Igiene, *11*, 1889, 354; Abst. in Cent. f. Bakt., *8*, 1890, 13.) From the normal skin of the human foot.

Micrococcus achrous Migula. (No. 16, Lembke, Arch. f. Hyg., *26*, 1896, 310; Migula, Syst. d. Bakt., *2*, 1900, 201.) From feces. Winslow and Winslow (Systematic Relationships of the Coccaceae, 1908, 224) state that this species is apparently a synonym of *Micrococcus candicans* Flügge.

Micrococcus acidi lactici Marpmann. (Ergänzungsheft d. Cent. f. allg. Gesundheitspflege, *2*, 1886, 22.) Found in fresh milk.

Micrococcus acidovorax Müller-Thurgau and Osterwalder. (Cent. f. Bakt., II Abt., *36*, 1913, 236.) From wine. Hucker (*loc. cit.*, 6) considers this a synonym of *Micrococcus luteus* Cohn or *Micrococcus varians* Migula.

Micrococcus acne Holland. (Jour. Bact., *5*, 1920, 223; *Staphylococcus acne* Holland, *ibid.*, 225; see *Micrococcus cutis communis* Sabouraud.)

Micrococcus (*Staphylococcus*) *acridicida* Kufferath. (Ann. de Gembloux, *27*, 1921, 253.) Isolated from diseased locusts from Greece. Resembles *Micrococcus aureus* Zopf.

Micrococcus aerius Chester. (No. 49, Conn, Storrs Agr. Exp. Sta. 7th Ann. Rept., 1895, 81; Chester, Man. Determ. Bact., 1901, 104.) From dust. Hucker (*loc. cit.*, 12) states that this species appears to be identical with *Micrococcus aureus* Zopf.

Micrococcus aerogenes Miller. (Miller, Deutsche med. Wehnschr., *12*, 1886, 119; not *Micrococcus aerogenes* Bergey et al., Manual, 1st ed., 1923, 70.) From the alimentary canal.

Micrococcus agilis albus Catterina. (Cent. f. Bakt., I Abt., Orig., *34*, 1903, 108.) Found in septicemia of rabbits. Motile with one or two flagella.

Micrococcus albatus Kern. (Arb. bakt. Inst. Karlsruhe, *1*, Heft 4, 1897, 479.) From the intestine of a woodpecker (*Picus major*). Winslow and Winslow (Systematic Relationships of the Coccaceae, 1908, 199) state that this species appears to be a synonym of *Micrococcus albus* Schroeter; while Hucker (N. Y. Agr. Exper. Sta., Tech. Bull. 102, 19) regards it as a synonym of *Micrococcus freudenreichii* Guillebeau or *Micrococcus ureae* Cohn.

Micrococcus albescens Henrici. (Arb. bakt. Inst. Karlsruhe, *1*, Heft 1, 1894, 76.) From cheese. Winslow and Winslow (*loc. cit.*, 199) state that this species appears to be a synonym of *Micrococcus albus* Schroeter; while Hucker (*loc. cit.*, 19) regards it as a synonym of *Micrococcus freudenreichii* Guillebeau or of *Micrococcus ureae* Cohn.

Micrococcus albidus Losski. (Losski, Inaug. Diss., Dorpat, 1893, 55; not *Micrococcus albidus* Henrici, see *Micrococcus subniveus* below; not *Micrococcus albidus* Roze, Compt. rend. Acad. Sci. Paris, *122*, 1896, 750.) From soil. Hucker (*loc. cit.*, 19) regards this species as a synonym of *Micrococcus freudenreichii* Guillebeau or *Micrococcus ureae* Cohn.

Micrococcus albocereus Migula. (*Staphylococcus cereus albus* Passet, Untersuch. ü. d. Aetiol. d. eiterigen Phlegmone d. Menschen, Berlin, 1885, 53, and Fortschr. d. Med., *3*, 1885; *Micrococcus cereus albus* Flügge, Die Mikroorganismen, 2 Aufl., 1886, 182; *Staphylococcus cereus* Trevisan, I generi e le specie delle Batteriacee, Milan, 1889, 32; Migula, Syst. d. Bakt., *2*, 1900, 56; *Staphylococcus cereus-albus* Holland, Jour. Bact., *5*, 1920, 225.) From human pus, also from water. Winslow and Winslow (Systematic Relationships of the Coccaceae, 1908, 205) consider this a synonym of *Micrococcus*

candidus Cohn or of *Gaffkya tetragena* Trevisan.

Micrococcus albus Frankland and Frankland. (Phil. Trans. Roy. Soc., London, *178*, B, 1888, 264; not *Micrococcus albus* Matzuschita, Cent. f. Bakt., I Abt., *29*, 1901, 382; not *Micrococcus albus* Buchanan, Veterinary Bacteriology, 1911, 196; not *Micrococcus albus* Macé, Traité Pratique de Bact., 6th éd., 1912, 605.) From air. Resembles *Micrococcus candicans*.

Micrococcus albus II Maggiora. (Cent. f. Bakt., *8*, 1890, 13.) See *Micrococcus opalescens* De Toni and Trevisan. From the skin of the human foot.

Micrococcus amplus Migula. (Grauweisser Diplococcus, Bumm, Der Mikroorg. d. gonorrh. Schleimhauterkrank., 1 Aufl., 1885, 17; *Micrococcus albicans amplus* Flügge, Die Mikroorganismen, 2 Aufl., 1886, 183; *Neisseria albicans* Trevisan, I generi e le specie delle Batteriacee, Milan, 1889, 32; *Diplococcus albicans amplus* Eisenberg, Bakt. Diag., 3 Aufl., 1891, 24; Migula, Syst. d. Bakt., *2*, 1900, 118; *Micrococcus albicans* Chester, Man. Determ. Bact., 1901, 80.) From vaginal secretions. Hucker (*loc. cit.*, 15) considers this species identical with *Micrococcus albus* Schroeter.

Micrococcus ampullaceus Kern. (Arb. bakt. Inst. Karlsruhe, *1*, Heft 4, 1897, 477.) From the intestine of a dove (*Columba oenas*). Hucker (*loc. cit.*, 19) considers this a synonym of *Micrococcus freudenreichii* Guillebeau or *Micrococcus ureae* Cohn.

Micrococcus annulatus Kern (*loc. cit.*, 490). From the stomach contents of the hedge sparrow (*Passer montanus*) and the intestine of the rock dove (*Columba livia*). Winslow and Winslow (Systematic Relationships of the Coccaceae, 1908, 216) consider this species a synonym of *Micrococcus flavus* Lehmann and Neumann.

Micrococcus aquatilis Bolton. (Zschr. f. Hyg., *1*, 1886, 94; not *Micrococcus aquatilis* Chester, see below.) From water. Winslow and Winslow (*loc. cit.*, 224) state that this species is apparently a synonym of *Micrococcus candicans* Flügge.

Micrococcus aquatilis Chester. (*Micrococcus aquatilis invisibilis* Vaughan, Amer. Jour. Med. Sci., *104*, 1892, 183; Chester, Man. Determ. Bact., 1901, 88.) From water. Winslow and Winslow (*loc. cit.*, 224) state that this species is apparently a synonym of *Micrococcus candicans* Flügge.

Micrococcus aquatilis albus. (Quoted from Toporoff, Protok. d. Kaiserl. kaukasisch Mediz. Gesellsch., 1892, No. 21; Abst. in Cent. f. Bakt., *13*, 1893, 487.) From water.

Micrococcus aquatilis flavus. (Quoted from Toporoff, *loc. cit.*) From water.

Micrococcus aqueus Migula. (No. 25, Lembke, Arch. f. Hyg., *26*, 1896, 317; Migula, Syst. d. Bakt., *2*, 1900, 204.) From feces. Winslow and Winslow (*loc. cit.*, 184) state that this species is apparently a synonym of *Micrococcus aureus* Zopf, while Hucker (*loc. cit.*, 15) regards this as a synonym of *Micrococcus albus* Schroeter.

Micrococcus arborescens lactis Conn. (Conn, Storrs Agr. Exp. Sta. 12th Ann. Rept., 1900, 46; *Micrococcus lactis arborescens* Conn, Esten and Stocking, Storrs Agr. Exp. Sta. 18th Ann. Rept., 1907, 110.) From milk. Hucker (*loc. cit.*, 21) regards this as a synonym of *Micrococcus candidus* Cohn or *Micrococcus epidermidis* Hucker.

Micrococcus argenteus Migula. (No. 27, Lembke, Arch. f. Hyg., *26*, 1896, 317; Migula, Syst. d. Bakt., *2*, 1900, 206.) From feces. Winslow and Winslow (*loc. cit.*, 184) state that this species is apparently a synonym of *Micrococcus aureus* Zopf, while Hucker (*loc. cit.*, 10) considers it a synonym of *Micrococcus conglomeratus* Migula.

Micrococcus ascoformans Johne. (*Zoogloea pulmonis equi* Bollinger, Arch. f. path. Anat., *49*, 1870, 583; *Discomyces equi* Rivolta, Giorn. di Anat. e Fisiolog.,

10, 1884; Johne, Ber. u. d. Veterin. im Königr. Sachsen, Jahr 1885, 47; *Ascococcus johnei* Cohn in letter to Johne, Deutsche Ztschr. f. Thiermed., *12*, 1886, 210; *Micrococcus botryogenus* Rabe, Deut. Ztschr. f. Thiermed., *12*, 1886, 137; *Botryomyces equi* Bollinger, Deut. Ztschr. f. Thiermed., *13*, 1887, 176; *Botryococcus ascoformans* Kitt, Cent. f. Bakt., *3*, 1888, 247; *Bollingera equi* Trevisan, I generi e le specie delle Batteriacee, Milan, 1889, 26; *Staphylococcus ascoformans* Ford, Textb. of Bact., 1927, 424; *Staphylococcus aureus* var. *equi* Hauduroy et al., Dict. d. Bact. Path., 1937, 504.) Causes botryomycosis in horses. Lehmann and Neumann (Bakt. Diag., 7 Aufl., *2*, 1927, 291) consider this a form of *Micrococcus aureus* Zopf; while Hucker (*loc. cit.*, 15) regards this as a form of *Micrococcus albus* Schroeter.

Micrococcus ascoformis Fermi. (Arch. f. Hyg., *10*, 1890, 10.) Presumably intended for *Micrococcus ascoformans* Johne.

Micrococcus asper Migula. (Seibert, Inaug. Diss., Würzburg, 1894, 12; Migula, Syst. d. Bakt., *2*, 1900, 82.) From a hairbrush. Winslow and Winslow (*loc. cit.*, 205) consider this species to be a synonym of *Micrococcus candidus* Cohn or of *Gaffkya tetragena* Trevisan.

Micrococcus aurantiacus-sorghi Bruyning. (Arch. Néer. Sci. Exact. et Nat., *1*, 1898, 297; *Streptococcus aurantiacus* Chester, Man. Determ. Bact., 1901, 69.) From sorghum.

Micrococcus aureus Chester. (*Micrococcus cremoides aureus* Dyar, Ann. N. Y. Acad. Sci., *8*, 1895, 349; Chester, Manual Determ. Bact., 1901, 99.) From dust. Regarded by Dyar as a varietal form of *Micrococcus cremoides* Zimmermann. Winslow and Winslow (*loc. cit.*, 184) consider this species a synonym of *Micrococcus aureus* Zopf.

Micrococcus aureus lactis Conn. (Storrs Agr. Exp. Sta. 12th Ann. Rept., 1900, 36.) From milk. This seems to be identical with *Micrococcus lactis aureus A*, Conn, Esten and Stocking, Storrs Agr. Exper. Sta. 18th Ann. Rept., 1907, 119. Hucker (*loc. cit.*, 9) regards this species as identical in part with *Micrococcus flavus* Lehmann and Neumann and with *Micrococcus conglomeratus* Migula.

Micrococcus (*Sarcina*) *baccatus* Migula. (No. 18, Lembke, Arch. f. Hyg., *26*, 1896, 311; Migula, Syst. d. Bakt., *2*, 1900, 202.) From feces. Winslow and Winslow (*loc. cit.*, 232) state that this is a yellow, gelatin-liquefying sarcina, apparently a synonym of *Sarcina flava* De Bary. Hucker (*loc. cit.*, 10) considers this a synonym of *Micrococcus conglomeratus* Migula.

Micrococcus badius Lehmann and Neumann. (Bakt. Diag., 1 Aufl., *2*, 1896, 163.) Received from the Kral collection as *Sarcina lutea*. Winslow and Winslow (*loc. cit.*, 216) consider this a synonym of *Micrococcus flavus* Lehmann and Neumann.

Micrococcus baregensis purpureus Robine and Hauduroy. (Compt. rend. Soc. Biol., Paris, *98*, 1928, 25.) From hot sulfur springs at Barèges.

Micrococcus beigelii (Rabenhorst) Migula. (*Pleurococcus beigelii* Küchenmeister and Rabenhorst, Hedwigia, 1867, No. 4; *Sclerotium beigelianum* Hallier, 1868; *Zoogloea beigeliana* Eberth, 1873; *Hyalococcus beigelii* Schroeter, Kryptog.-Flora v. Schlesien, *3*, 1, 1886, 152; *Chlamydatomus beigelii* Trevisan, Rendiconti Reale Inst. Lombardo de Sci. e Lett., Ser. II, *12*, 1879, 22; Migula, Syst. d. Bakt., *2*, 1900, 193; *Trichosporum beigelii* Vuillemin, 1901.) From human hair.

Micrococcus beri-beri Pekelharing. (Pekelharing, Weekblad v. h. Ned. Tijdschr. v. Geneesk., No. 25; also Pekelharing and Winkler, Deut. med. Wchnschr., No. 39, 1887, 845; *Neisseria winkleri* Trevisan, I generi e le specie delle Batteriacee, Milan, 1889, 32.) Considered the cause of beri-beri by Pekelharing. Winslow and Winslow (*loc. cit.*, 184) state that this is apparently a synonym of *Micrococcus aureus* Zopf; while Hucker (*loc. cit.*, 11) considers

this a synonym of *Micrococcus citreus* Migula.

Micrococcus bicolor Kern. (Arb. bakt. Inst. Karlsruhe, *1*, Heft 4, 1897, 485.) From the intestine of a dove (*Columba oenas*). Hucker (*loc. cit.*, 21) considers this a synonym of *Micrococcus candidus* Cohn or of *Micrococcus epidermidis* Hucker.

Micrococcus billrothii (Cohn) Migula. (*Ascococcus billrothii* Cohn, Beitr. z. Biol. d. Pflanzen, *1*, Heft 3, 1875, 151; Migula, Syst. d. Bakt., *2*, 1900, 195.) Found in putrefying meat infusion.

Micrococcus biskra Heydenreich. (Heydenreich, Ausgabe d. Haupt Med.-Verhalt., St. Petersburg, 1888; see Cent. f. Bakt., *5*, 1889, 163; *Staphylococcus biskrae* Trevisan, I generi e le specie delle Batteriacee, Milan, 1889, 32; *Micrococcus heydenreichii* Chester, Man. Determ. Bact., 1901, 91.) Found in ulcers in an Oriental skin disease. Winslow and Winslow (*loc. cit.*, 184) state that this is apparently a synonym of *Micrococcus aureus* Zopf; while Hucker (*loc. cit.*, 11) considers it a synonym of *Micrococcus citreus* Migula.

Micrococcus boleti Passerini. (Erbar. crittogam. Italiano, II ser., No. 1199; quoted from Trevisan, I generi e le specie delle Batteriacee, Milan, 1889, 34.) Saprophytic on a fungus (*Boletus edulis*).

Micrococcus bombycis (Naegeli) Cohn. (*Panhistophyton ovatum* Lebert, Jahresber. ü. d. Wirksamkeit d. Vereins z. Beförd. d. Seidenbaues f. Brandenburg im Jahre 1856–57, 28; and Berliner Entomolog. Ztschr., 1858; *Nosema bombycis* Naegeli, Botan. Sect. d. 33 Versammlg. d. Naturf. u. Aerzte in Bonn, 1857, 160; and Botan. Zeitg., 1857, 760; *Microzyma bombycis* Béchamp, Compt. rend. Acad. Sci., Paris, *64*, 1867, 1045; Cohn, Beitr. z. Biol. d. Pflanzen, *1*, Heft 2, 1872, 165; *Micrococcus ovatus* Winter, in Rabenhorst, Krypt. Flora v. Deutschl., Oesterr. u. d. Schweiz, 2 Aufl., *1*, 1884, 47; *Streptococcus bombycis* Zopf, Die Spaltpilze, 2 Aufl., 1884, 52.) Found in the blood and organs of diseased silkworms (*Bombyx mori*).

Micrococcus boreus Issatchenko. (Recherches sur les Microbes de l'Océán Glacial Arctique, Petrograd, 1914, 144.) From sea water.

Micrococcus bovinus Migula. (Micrococcus der Lungenseuche der Rinder, Poels and Nolen, Fortschr. d. Med., 1886, 217; Migula, Syst. d. Bakt., *2*, 1900, 67.) From the lungs of diseased cattle. Hucker (*loc. cit.*, 22) regards this a synonym of *Micrococcus candidus* Cohn or of *Micrococcus epidermidis* Hucker.

Micrococcus bovis Migula. (Hematococcus, Babes, Compt. rend. Acad. Sci., Paris, *107*, 1888, 692 and *110*, 1890, 800 and 975; also see Arch. f. path. Anat., *115*, 1889; *Neisseria babesi* Trevisan, I generi e le specie delle Batteriacee, Milan, 1889, 32; *Haematococcus bovis* Eisenberg, Bakt. Diag., 3 Aufl., 1891, 271; Migula, Syst. d. Bakt., *2*, 1900, 85.) From the blood and organs of cattle.

Micrococcus burchardti Trevisan. (Coccus bei keratitis phlyctaenulosa, Burchardt, Cent. f. Bakt., *1*, 1887, 392; Trevisan, I generi e le specie delle Batteriacee, Milan, 1889, 33.) Pathogenic. From the cornea of a rabbit.

Micrococcus butyri (v. Klecki) Migula. (*Diplococcus butyri* von Klecki, Cent. f. Bakt., *16*, 1894, 358; Migula, Syst. d. Bakt., *2*, 1900, 216.) From rancid butter. Winslow and Winslow (*loc. cit.*, 220) consider this a synonym of *Micrococcus luteus* Cohn.

Micrococcus butyri fluorescens Teichert. (Inaug. Diss., Jena, 1904; Abst. in Cent. f. Bakt., II Abt., *13*, 1904, 561.) From milk. Exhibits a green fluorescence.

Micrococcus butyricus (von Klecki) Migula. (*Tetracoccus butyricus* von Klecki, Cent. f. Bakt., *15*, 1894, 360; Migula, Syst. d. Bakt., *2*, 1900, 216.) From rancid butter. Winslow and Winslow (*loc. cit.*, *220*) consider this a synonym of *Micrococcus luteus* Cohn.

Micrococcus calco-aceticus Beijerinck. (Proc. Sect. Sci., Kon. Akad. v. Wetenschappen, *13*, 1911, 1066; Abst. in Cent. f. Bakt., II Abt., *31*, 1912, 290.) Occurs commonly in soils.

Micrococcus campeneus Orme. (Jour. Trop. Med. and Hyg., *11*, 1908, No. 10, May 15; Abst. in Cent. f. Bakt., I Abt., Ref., *43*, 1909, 299.)

Micrococcus candicans Flügge. (Die Mikroorganismen, 2 Aufl., 1886, 173; *Albococcus candicans* Winslow and Rogers, Jour. Inf. Dis., *3*, 1906, 544; *Staphylococcus candicans* Holland, Jour. Bact., *5*, 1920, 225.) From air, water and milk. Hucker (*loc. cit.*, 22) regards this a synonym of *Micrococcus candidus* Cohn or of *Micrococcus epidermidis* Hucker. For a description of this species, see Bergey et al., Manual, 5th ed., 1939, 255.

Micrococcus canescens Migula. (Micrococcus No. 4, Adametz, Landwirtsch. Jahrb., *18*, 1889, 240; Migula, Syst. d. Bakt., *2*, 1900, 51; *Albococcus canescens* Winslow and Rogers, Jour. Inf. Dis., *3*, 1906, 544; *Staphylococcus canescens* Holland, Jour. Bact., *5*, 1920, 225.) From Emmenthal cheese. Winslow and Winslow (*loc. cit.*, 224) state that this is apparently a synonym of *Micrococcus candicans* Flügge.

Micrococcus capillorum (Buhl) Trevisan. (*Zoogloea capillorum* Buhl, Ztschr. f. ration. Med., II Reihe, *14*, 18–, 356; *Palmella capillorum* Kühn, Abhandl. d. Naturf. Ges. zu Halle, *9*, Heft 1, 18–, 62; *Palmellina capillorum* Rabenhorst, Flor. Eur. Alg., 3, 1856 (?), 35; Trevisan, I generi e le specie delle Batteriacee, Milan, 1889, 33.) From the skin. Considered pathogenic.

Micrococcus capsaformans Jamieson and Edington. (Brit. Med. Jour., *1*, June 11, 1887, 1262; *Micrococcus capriformis* (sic), Abst. in Cent. f. Bakt., *2*, 1887, 223.) From the scales and blood of scarlet fever patients. Not pathogenic.

Micrococcus carbo Renault. (Compt. rend. Acad. Sci., Paris, *123*, 1896, 935.)

Micrococcus carneus Zimmermann. (Roter Coccus, Maschek. Bakt. Untersuch d. Leitmeritz. Trinkwassers, No. 5, 1887, 60; Zimmermann, Die Bakt. unserer Trink- u. Nutzwässer, Chemnitz, I Reihe, 1890, 78.) From water. Hucker (*loc. cit.*, 25 and 26) regards this species as identical with *Micrococcus roseus* Flügge or *Micrococcus cinnabareus* Flügge.

Micrococcus carnicolor Frankland and Frankland. (Phil. Trans. Roy. Soc. London, *178*, B, 1888, 263; not *Micrococcus carnicolor* Kern, see *Micrococcus subcarneus* below.) From air. Hucker (*loc. cit.*, 25) states that this species may be identical with *Micrococcus roseus* Flügge.

Micrococcus carniphilus Wilhelmy. (Arb. bakt. Inst. Karlsruhe, *3*, 1903, 10.) From a meat extract.

Micrococcus casei amari edamicus Raamot. (Inaug. Diss., Königsberg, 1906; Abst. in Cent. f. Bakt., II Abt., *18*, 1907, 348.) From pasteurized skim milk.

Micrococcus castellanii Chalmers and O'Farrell. (Ann. Trop. Med. and Parasitol., *7*, 1913, 528; *Rhodococcus castellanii* Castellani and Chalmers, Man. Trop. Med., 3rd ed., 1919, 2102.) Found in the red variety of trichomycosis axillaris, a tropical disease.

Micrococcus cartharinensis Issatchenko. (Recherches sur les Microbes de l'Oceán Glacial Artique, Petrograd, 1914, 148.) From sea water.

Micrococcus cellaris (Schroeter) Migula. (*Leucocystis cellaris* Schroeter, Kryptog. Flora v. Schlesien, *3*, 1886, 152; Migula, Syst. d. Bakt., *2*, 1900, 195.) From a coating on the walls of damp cellars and mines.

Micrococcus centropunctatus Issatchenko. (Recherches sur les Microbes de l'Oceán Glacial Arctique, Petrograd, 1914, 146.) From sea water.

Micrococcus cerasinus Migula. (Micrococcus aus roter Milch, Keferstein; Cent. f. Bakt., I Abt., *21*, 1897, 177; *Micrococcus cerasinus lactis* Heim, Lehrb.

d. Bakt., 2 Aufl., 1898, 299; Migula, Syst. d. Bakt., *2*, 1900, 170; not *Micrococcus cerasinus* Lehmann and Neumann, Bakt. Diag., 1 Aufl., *2*, 1896, 179; *Micrococcus kefersteinii* Chester, Man. Determ. Bact., 1901, 107.) From red milk. Hucker (*loc. cit.*, 26) regards this species as identical with *Micrococcus cinnabareus* Flügge.

Micrococcus cereus Migula. (*Staphylococcus cereus flavus* Passet, Untersuchungen über die Aetiologie der eiterigen Phlegmone des Menschen, 1885, 53; *Micrococcus cereus flavus* Flügge, Die Mikroorganismen, 2 Aufl., 1886, 182; *Staphylococcus passeti* Trevisan, I generi e le specie delle Batteriacee, Milan, 1889, 32; Migula, Syst. d. Bakt., *2*, 1900, 126; *Staphylococcus cereus-flavus* Holland, Jour. Bact., *5*, 1920, 225.) From pus. Winslow and Winslow (*loc. cit.*, 220) consider this species identical with *Micrococcus luteus* Migula. For a description of this organism, see Bergey et al., Manual, 5th ed., 1939, 241.

Micrococcus cereus aureus Dyar. (Ann. N. Y. Acad. Sci., *8*, 1895, 347.) Obtained as *Staphylococcus cereus aureus* from Kral's laboratory; also found in air.

Micrococcus cerinus Henrici. (Arb. bakt. Inst. Karlsruhe, *1*, Heft 1, 1894, 84.) From Swiss cheese. Winslow and Winslow (*loc. cit.*, 216) consider this a synonym of *Micrococcus flavus* Trevisan.

Micrococcus chersonesia Corbet. (Quart. Jour. Rubber Research Inst., Malaya, *2*, 1930, 150.) From the latex of the rubber tree (*Hevea brasiliensis*). For a description of this species, see Bergey et al., Manual, 5th ed., 1939, 258.

Micrococcus chinicus Emmerling and Abderhalden. (Cent. f. Bakt., II Abt., *10*, 1902, 337.) Putrefying meat.

Micrococcus chlorinus Cohn. (Grüngelber Coccus, Maschek, Jahresber. d. Kom.- Oberrealschule zu Leitmeritz, 1887, 66; Cohn, Beitr. z. Biol. d. Pflanzen, *1*, Heft 2, 1872, 155.) From water and dust. Hucker (*loc. cit.*, 10) considers this a synonym of *Micrococcus conglomeratus* Migula.

Micrococcus chromidrogenus citreus Trommsdorff. (Münch. Med. Wochnschr., 1904, No. 29, 1286; Abst. in Cent. f. Bakt., I Abt., Ref., *37*, 1905, 60.) Isolated from a case of chromidrosis of the axilla.

Micrococcus chromidrogenus ruber Trommsdorff (*loc. cit.*). Isolated from a case of chromidrosis of the axilla.

Micrococcus chromoflavus Huss. (Cent. f. Bakt., II Abt., *19*, 1907, 520.) From cheese

Micrococcus chryseus Frankland and Frankland. (Phil. Trans. Roy. Soc. London, 178, B, 1888, 268.) From dust. Winslow and Winslow (*loc. cit.*, 184) state that this species is apparently a synonym of *Micrococcus aureus* Zopf.

Micrococcus cinnabarinus Zimmermann. (Die Bakt. unserer Trink- u. Nutzwässer, Chemnitz, I Reihe, 1890, 76.) From water. Hucker (*loc. cit.*, 26) regards this species as identical with *Micrococcus cinnabareus* Flügge.

Micrococcus cirrhiformis Migula. (Ranken Coccus, Maschek, Jahresber. d. Kom.- Oberrealschule in Leitmeritz, 1887, 66; Migula, Syst. d. Bakt., *2*, 1900, 53.) From water. Hucker (*loc. cit.*, 22) considers this a synonym of *Micrococcus candidus* Cohn or of *Micrococcus epidermidis* Hucker.

Micrococcus citreus I and *II*, Maggiora. (Giorn. Soc. Ital. d'Igiene, *11*, 1889, 354; Abst. in Cent. f. Bakt., *8*, 1890, 13; not *Micrococcus citreus* Eisenberg, Bakt. Diag., 3 Aufl., 1891, 36; not *Micrococcus citreus* Migula, Syst. d. Bakt., *2*, 1900, 147; not *Micrococcus citreus* Winslow and Winslow, Systematic Relationships of the Coccaceae, 1908, 218.) From the normal skin of the foot.

Micrococcus citreus granulatus Freund. (Inaug. Diss., Erlangen, 1893, 27; Abst. in Cent. f. Bakt., *16*, 1894, 641; *Micrococcus granulatus* Bazarewski, Cent. f. Bakt., II Abt., *15*, 1905, 7; not *Micrococcus granulatus* Weiss, Arb. bakt. Inst.

Karlsruhe, *2*, Heft 3, 1902, 197.) From the oral cavity. Hucker (*loc. cit.*, 9) regards this as a synonym of *Micrococcus flavus* Trevisan.

Micrococcus citreus lactis Conn. (Storrs Agr. Exp. Sta. 12th Ann. Rept., 1900, 40.) From milk. Hucker (*loc. cit.*, 10) considers this a synonym of *Micrococcus conglomeratus* Migula.

Micrococcus citreus rigensis Bazarewski. (Cent. f. Bakt., II Abt., *15*, 1905, 5.) From dust.

Micrococcus citrinus Migula. (*Diplococcus citreus liquefaciens* Unna and Tommasoli, Monats. f. prakt. Dermatologie, *9*, 1889, 56; Migula, Syst. d. Bakt., *2*, 1900, 150; *Micrococcus tommasoli* Chester, Man. Determ. Bact., 1901, 101; *Micrococcus citreus liquefaciens* Winslow and Winslow, Systematic Relationships of the Coccaceae, 1908, 216.) From human skin in a case of eczema. Winslow and Winslow (*loc. cit.*, 216) consider this a synonym of *Micrococcus flavus* Trevisan.

Micrococcus claviformis von Besser. (Beitr. z. path. Anat. u. z. allgem. Path., *6*, 1889, 340; see Cent. f. Bakt., *7*, 1890, 152.) Found once in nasal secretions.

Micrococcus coccineus Migula. (Micrococcus No. VI, Adametz, Landwirtsch. Jahrb., *18*, 1889, 242; Migula, Syst. d. Bakt., *2*, 1900, 174.) From Emmenthal cheese. Hucker (*loc. cit.*, 26) regards this species identical with *Micrococcus cinnabareus* Flügge.

Micrococcus coli brevis Lehmann. (Lehmann, Inaug. Diss., München, 1903; Abst. in Cent. f. Bakt., I Abt., Ref., *36*, 1905, 688.) From feces of infants.

Micrococcus communis lactis Conn. (Storrs Agr. Exp. Sta. 12th Ann. Rept., 1900, 48.) From milk. Hucker (*loc. cit.*, 19) considers this a synonym of *Micrococcus freudenreichii* Guillebeau or of *Micrococcus ureae* Cohn.

Micrococcus commensalis (Turró) Migula. (*Diplococcus commensalis* Turró, Cent. f. Bakt., *16*, 1894, 1; Migula, Syst. d. Bakt., *2*, 1900, 125.) From sputum. Winslow and Winslow (*loc. cit.*, 220) consider this a synonym of *Micrococcus luteus* Cohn.

Micrococcus commutatus De Toni and Trevisan. (*Micrococcus albus I* or *Micrococcus albus fluidificans* Maggiora, Giorn. Soc. Ital. d'Igiene, *11*, 1889, 350; De Toni and Trevisan, in Saccardo, Sylloge Fungorum, *8*, 1889, 1079.)

Micrococcus concentricus Zimmermann. (Die Bakt. unserer Trink- u. Nutzwässer, Chemnitz, I Reihe, 1890, 86.) From water. Winslow and Winslow (*loc. cit.*, 224) state that this is apparently a synonym of *Micrococcus candicans* Flügge.

Micrococcus confluens Kern. (Arb. bakt. Inst. Karlsruhe, *1*, Heft 4, 1897, 494.) From the stomach and intestine of the starling (*Sturnus vulgaris*) and the finch (*Fringella carduelis*). Winslow and Winslow (*loc. cit.*, 216) consider this a synonym of *Micrococcus flavus* Trevisan.

Micrococcus conjunctivae Migula. (*Micrococcus liquefaciens conjunctivae* Gombert, Recherches expérimentales sur les microbes des conjunctives, Montpellier and Paris, 1889; Migula, Syst. d. Bakt., *2*, 1900, 115.) From normal human conjunctiva. Hucker (*loc. cit.*, 15) considers this a synonym of *Micrococcus albus* Schroeter.

Micrococcus conjunctividis Migula. (*Micrococcus flavus conjunctivae* Gombert, Recherches expérimentales sur les microbes des conjunctives, Montpellier and Paris, 1889; Migula, Syst. d. Bakt., *2*, 1900, 141.) From normal human conjunctiva. Winslow and Winslow (*loc. cit.*, 216) consider this a synonym of *Micrococcus flavus* Trevisan; while Hucker (*loc. cit.*, 11) regards it as a synonym of *Micrococcus citreus* Migula.

Micrococcus conoideus Migula. (*Staphylococcus salivarius pyogenes* Biondi, Ztschr. f. Hyg., *2*, 1887, 227; *Staphylococcus sialopyus* Trevisan, I generi e le specie delle Batteriacee, Milan, 1889,

32; *Micrococcus salivarius pyogenes* Freire, Mémoire sur la bactériologie, pathogénie, traitement et prophylaxie de la fievre jaune. Rio de Janiero, 1898; Abst. in Cent. f. Bakt., I Abt., *26*, 1899, 741; *Staphylococcus pyogenes salivarius*, quoted from Goadby, Trans. of Odontolog. Society, June, 1899, see Abst. in Cent. f. Bakt., I Abt., Ref., *31*, 1902, 493; Migula, Syst. d. Bakt., *2*, 1900, 102.) From saliva. Hucker (*loc. cit.*, 12 and 15) regards this as a synonym of *Micrococcus aureus* Zopf or of *Micrococcus albus* Schroeter.

Micrococcus corallinus Cantani. (Cantani, Cent. f. Bakt., I Abt., *23*, 1898, 311; *Rhodococcus coralinus* (sic) Levine and Soppeland, Iowa State Coll. Engineering Exp. Sta. Bul. 77, 1926, 22.) From dust. Hucker (*loc. cit.*, 25) considers this a synonym of *Micrococcus roseus* Flügge. Levine and Soppeland (*loc. cit.*) regard this as a synonym of *Rhodococcus fulvus* Winslow and Rogers. For a description of this species, see Bergey et al., Manual, 5th ed., 1939, 253.

Micrococcus coralloides Zimmermann. (Die Bakt. unserer Trink- u. Nutzwässer, Chemnitz, II Reihe, 1894, 72.) From water. Winslow and Winslow (*loc. cit.*, 199) state that this species appears to be a synonym of *Micrococcus albus* Zopf; while Hucker (*loc. cit.*, 17) considers it a synonym of *Micrococcus caseolyticus* Evans.

Micrococcus corrugatus Migula. (*Merismopedia mesentericus corrugatus* Dyar, Ann. N. Y. Acad. Sci., *8*, 1895, 355; Migula, Syst. d. Bakt., *2*, 1900, 161.) From dust. Winslow and Winslow (*loc. cit.*, 216) consider this a synonym of *Micrococcus flavus* Trevisan.

Micrococcus coryzae (Hajek) Migula. (*Diplococcus coryzae* Hajek, Berliner klin. Wochnschr., No. 33, 1888; Migula, Syst. d. Bakt., *2*, 1900, 63.) From secretions in acute catarrh. Winslow and Winslow (*loc. cit.*, 205) consider this a synonym of *Micrococcus candidus* Cohn or of *Gaffkya tetragena* Trevisan.

Micrococcus cremoides Zimmermann. (Die Bakt. unserer Trink- u. Nutzwässer, Chemnitz, I Reihe, 1890, 74.) From water. Winslow and Winslow (*loc. cit.*, 216) consider this a synonym of *Micrococcus flavus* Trevisan; while Hucker (*loc. cit.*, 10) considers it a synonym of *Micrococcus conglomeratus* Migula.

Micrococcus cremoides albus Dyar. (Ann. N. Y. Acad. Sci., *8*, 1895, 350). From dust. Regarded by Dyar as a white form of *Micrococcus cremoides* Zimmermann.

Micrococcus cremorisviscosi (Hammer and Cordes) Bergey et al. (*Staphylococcus cremoris-viscosi* Hammer and Cordes, Jour. Dairy Sci., *3*, 1920, 291; Bergey et al., Manual, 3rd ed., 1930, 86.) From ropy milk. For a description of this species, see Bergey et al., Manual, 5th ed., 1939, 254.

Micrococcus crepusculum (Ehrenberg) Cohn. (*Monas crepusculum* Ehrenberg, Abhandl. d. Berliner Akad., 1830, 74 and 1832, 57; Cohn, Beitr. z. Biol. d. Pflanzen, *1*, Heft 2, 1872, 160.) De Toni and Trevisan (in Saccardo, Sylloge Fungorum, *8*, 1889, 1082) list the following as synonyms of this species; *Protococcus nebulosus* Kützing, Linneae, *8*, 1833, 365; *Cryptococcus nebulosus* Kützing, Phycol. gener., 1845, 147; *Cryptococcus natans* Kützing, Spec. Alg., 1849, 146.

Micrococcus cretaceus Henrici. (Arb. bakt. Inst. Karlsruhe, *1*, Heft 1, 1894, 65.) From cheese. Winslow and Winslow (*loc. cit.*, 224) state that this is apparently a synonym of *Micrococcus candicans* Flügge.

Micrococcus cristatus Glage. (Ztschr. f. Fleisch- u. Milch-hygiene, *10*, 1900, 145.) From the surface of wurst and similar meat products.

Micrococcus cruciformis Freire. (Compt. rend. Acad. Sci., Paris, *128*, 1899, 1047.) From the stamens and pistils of *Hibiscus*.

Micrococcus cumulatus Kern. (Arb. bakt. Inst. Karlsruhe, *1*, Heft 4, 1897, 497; not *Micrococcus cumulatus* Chester,

see *Micrococcus tenuissimus* Migula.) From the stomach and intestine of the yellow-hammer (*Emberiza citrinella*) and of the finch (*Fringella carduelis*). Hucker (*loc. cit.*, 25) regards this as a synonym of *Micrococcus roseus* Flügge.

Micrococcus cupularis Migula. (No. 29, Lembke, Arch. f. Hyg., *29*, 1897, 331; Migula, Syst. d. Bakt., *2*, 1900, 211.) From feces. Winslow and Winslow (*loc. cit.*, 216) consider this a synonym of *Micrococcus flavus* Trevisan.

Micrococcus cupuliformis Migula. (No. 19, Lembke, Arch. f. Hyg., *29*, 1897, 325; Migula, Syst. d. Bakt., *2*, 1900, 213.) From feces. Winslow and Winslow (*loc. cit.*, 220) consider this a synonym of *Micrococcus luteus* Cohn.

Micrococcus curtissi Chorine. (Chorine, Internat. Corn Borer Invest. Chicago, *2*, 1929, 48.) From diseased larvae of the corn borer (*Pyrausta nubilalis*). Also virulent to larvae of the flour moth (*Ephestia kühniella*) and of the bee moth (*Galleria mellonella*).

Micrococcus cutis communis Sabouraud. (Sabouraud, Ann. d. dermatol. et syphil., 1896, Heft 3; Abst. in Cent. f. Bakt., I Abt., *20*, 1896, 249; *Staphylococcus cutis communis* Sabouraud, Practique Dermatologique, *1*, 1903, 714.) From human skin especially in alopecia areata, certain types of eczema and acne. May be the same as *Micrococcus epidermidis* Hucker.

Micrococcus cyaneus (Schroeter) Cohn. (*Bacteridium cyaneum* Schroeter, Beitr. z. Biol. d. Pflanzen, *1*, Heft 2, 1872, 122 and 126; Cohn, *ibid.*, 156; *Nigrococcus cyaneus* Castellani and Chalmers, Man. Trop. Med., 3rd ed., 1919, 932.) From dust and water.

Micrococcus cyanogenus Pammel and Combs. (Proc. Iowa Acad. Sci., *3*, 1895, 136; see Abst. in Cent. f. Bakt., II Abt., *2*, 1896, 764.) From milk.

Micrococcus cyclops Henrici. (Arb. bakt. Inst. Karlsruhe, *1*, Heft 1, 1894, 69.) From Swiss cheese. Winslow and Winslow (*loc. cit.*, 224) state that this is apparently a synonym of *Micrococcus candicans* Flügge.

Micrococcus cystiopoeus Müller-Thurgau. (Cent. f. Bakt., II Abt., *20*, 1908 464.) From wine.

Micrococcus cytophagus Merker. (Cent. f. Bakt., II Abt., *31*, 1912, 589.) Found on the leaves of *Elodea*. Utilizes cellulose. Stanier (Bact. Rev., *6*, 1942 150) thinks that these micrococci were microcysts of *Sporocytophaga spp.*

Micrococcus dantecii Chester. (Coccus du rouge de morue, Le Dantec, Ann. Past. Inst., *5*, 1891, 662; Chester, Man. Determ. Bact., 1901, 106.) From red salted codfish. Hucker (*loc. cit.*, 25) considers this a synonym of *Micrococcus roseus* Flügge.

Micrococcus decalvens (Thin) Schroeter. (*Bacterium decalvens* Thin, Monats. f. prakt. Dermatol., No. 28, 1885; Schroeter in Cohn, Kryptog.-Flora v. Schlesien, *3*, 1, 1886, 149.) From hair follicles in alopecia areata.

Micrococcus decipiens Trevisan. (Bactérie de l'air, Cornil and Babes, Les Bactéries, 1885, 124; Trevisan, I generi e le specie delle Batteriacee, Milan, 1889, 34.) From dust.

Micrococcus (*Streptococcus* ?) *decolor* Migula. (No. 22, Lembke, Arch. f. Hyg., *26*, 1896, 311; Migula, Syst. d. Bakt., *2*, 1900, 203.) From feces. Hucker (*loc. cit.*, 17) considers this a synonym of *Micrococcus caseolyticus* Evans.

Micrococcus deformans Crowe. (Brit. Med. Jour., Nov. 27, 1920, 815; Abst. in Cent. f. Bakt., I Abt., Ref., *73*, 1922, 84.) From cases of arthritis. A form of *Micrococcus pyogenes albus* according to Lehmann and Neumann (Bakt. Diag., 7 Aufl., *2*, 1927, 293).

Micrococcus delacourianus Roze. (Compt. rend. Acad. Sci., Paris, *123*, 1896, 613 and 1323.) From dry rotting potatoes.

Micrococcus dendroporthos Ludwig. (Cent. f. Bakt., *10*, 1891, 10.) From the bark of poplar trees (*Populus sp.*).

Micrococcus denitrificans Beijerinck. (Cent. f. Bakt., II Abt., *25*, 1910, 53.) From Rochelle salts (sodium potassium tartrate).

Micrococcus dermatogenes Fuhrmann. (Cent. f. Bakt., II Abt., *17*, 1906, 618.) From bottled beer.

Micrococcus diffluens Schroeter. (In Cohn, Kryptog.-Flora v. Schlesien, *3*, 1, 1886, 144.) From dust, feces, etc.

Micrococcus dimorphus Bucherer. (Planta, Arch. f. wissen. Bot., 1934, 98.) A dimorphic bacterium. He reports it as much like *Micrococcus melitensis* Bruce and *Bacterium fraenkelii* Hashimoto.

Micrococcus diphtericus (sic) Cohn. (*Micrococcus*, Oertel, Deutsch. Arch. f. klin. Med., *8*, 1871; Cohn, Beitr. z. Biol. d. Pflanzen, *1*, Heft 2, 1872, 162; *Streptococcus diphtheriticus* Zopf, Die Spaltpilze, 3 Aufl., 1885, 53.) From throats and nasal passages of diphtheria patients.

Micrococcus dissimilis Dyar. (See Sattler, Cent. f. Bakt., *5*, 1889, 70; Dyar, Ann. N. Y. Acad. Sci., *8*, 1895, 353; *Micrococcus trachomatis conjunctivae* Sattler in Kral, Die gegenwartigen Bestand der Kral'schen Sammlung von Mikroorganismen, 1900, 19.) From trachoma infections. Hucker (*loc. cit.*, 17) considers this a synonym of *Micrococcus caseolyticus* Evans.

Micrococcus djokjakartensis Zettnow. (Cent. f. Bakt., I Abt., Orig., *75*, 1915, 376.) From a sugar factory in Java.

Micrococcus doyeni De Toni and Trevisan. (*Micrococcus urinae albus olearius* Doyen, Jour. d. connaiss. médic., No. 14, 1889, 108; De Toni and Trevisan, in Saccardo, Sylloge Fungorum, *8*, 1889, 1076.) From urine. Hucker (*loc. cit.*, 16) states that this species is apparently identical with *Micrococcus albus* Schroeter.

Micrococcus drimophylus Baumgartner. (Baumgartner, Ergebnisse d. ges. Zahnheilk., Heft 2, 1910, 729; Abst. in Cent. f. Bakt., I Abt., Ref., *48*, 1911, 622.) From the mouth cavity.

Micrococcus eatonii Corbet. (Quart. Jour. Rubber Research Inst. Malaya, *2*, 1930, 145.) From the latex of the rubber tree (*Hevea brasiliensis*). For a description of this species, see Bergey et al., Manual, 5th ed., 1939, 244.

Micrococcus eburneus Henrici. (Arb. bakt. Inst. Karlsruhe, *1*, Heft 1, 1894, 85.) From Camembert cheese. Winslow and Winslow (*loc. cit.*, 224) state that this species is apparently a synonym of *Micrococcus candicans* Flügge.

Micrococcus ephestiae Mattes. (Sitzungsber. d. Gesellsch. z. Beförd. d. gesamt. Naturwissensch. zu Marburg, *62*, 1927, 406.) From the Mediterranean flour moth (*Ephestia kuehniella*).

Micrococcus epimetheus Corbet (*loc. cit.*, 148). From the latex of the rubber tree (*Hevea brasiliensis*). For a description of this species, see Bergey et al., Manual, 5th ed., 1939, 256.

Micrococcus esterificans Beck. (Arb. kaiserl. Gesundheitsamte, *29*, Heft 2, 1905; Abst. in Cent. f. Bakt., II Abt., *19*, 1907, 594.) Has a characteristic fruity aroma. From butter.

Micrococcus exanthematicus Lewascheff. (Deutsch. med. Wochnschr., No. 13 and 34, 1892; Abst. in Cent. f. Bakt., *12*, 1892, 635.) From blood in cases of typhus fever. Motile. Grows anaerobically.

Micrococcus excavatus Kern. (Arb. bakt. Inst. Karlsruhe, *1*, Heft 4, 1897, 486.) From the stomach contents of a coot (*Fulica atra*) and a woodpecker (*Picus major*). Winslow and Winslow (*loc. cit.*, 220) consider this a synonym of *Micrococcus luteus* Cohn.

Micrococcus exiguus Kern (*loc. cit.*, 470). From the stomach contents of the chaffinch (*Fringella coelebs*). Winslow and Winslow (*loc. cit.*, 199) state that this appears to be a synonym of *Micrococcus albus* Schroeter; while Hucker (*loc. cit.*, 19) considers it a synonym of *Micrococcus freudenreichii* Guillebeau or of *Micrococcus ureae* Cohn.

Micrococcus expositionis Chester. (No.

34, Conn, Storrs Agr. Exp. Sta. 7th Ann. Rept., 1895, 77; Chester, Man. Determ. Bact., 1901, 92.) From air. Winslow and Winslow (*loc. cit.* 216) consider this a synonym of *Micrococcus flavus* Trevisan; while Hucker (*loc. cit.*, 10) regards it as a synonym of *Micrococcus conglomeratus* Migula.

Micrococcus expressus Weiss. (Arb. bakt. Inst. Karlsruhe, *2*, Heft 3, 1902, 195.) From a carrot infusion. Produces slime. Hucker (*loc. cit.*, 7) considers this species a synonym of *Micrococcus luteus* Cohn or of *Micrococcus varians* Migula.

Micrococcus faviformis Migula. (Milchweisser Diplococcus, Bumm, Mikroorg. d. gonorrh. Schleimbautkr., II Ausg., 1887, 18; *Micrococcus lacteus faviformis* Flügge, Die Mikroorganismen, 2 Aufl., 1886, 182; *Neisseria lactea* Trevisan, I generi e le specie delle Batteriacee, Milan, 1889, 32; Migula, Syst. d. Bakt., *2*, 1900, 117.) From vaginal and other body secretions. Winslow and Winslow (*loc. cit.*, 199) state that this appears to be a synonym of *Micrococcus albus* Schroeter.

Micrococcus feddei Herter. (Micrococcus XVI, Choukevitch, Ann. Inst. Past., *25*, 1911, 354; Botan. Jahresber., *39*, II Abt., Heft 4, 1914, 755; Abst. in Cent. f. Bakt., II Abt., *51*, 1920, 367.) From the large intestine of a horse. Resembles *Micrococcus roscidur* Matzuschita.

Micrococcus fervitosus Adametz and Wichmann (Bakt. d. Trink- u. Nutzwässer, Mitt. Oest. Versuchstat. f. Brauerei u. Mälzerei, Wien, Heft 1, 1888.) From water. Winslow and Winslow (*loc. cit.*, 205) consider this a synonym of *Gaffkya tetragena* Trevisan.

Micrococcus fickii Trevisan. (*Coccus albus non liquefaciens* (*Coccus candicans*) Fick, Ueber Microorg. in Conjunctivalsack, Wiesbaden, 1887; Trevisan, I generi e le specie delle Batteriacee, Milan, 1889, 33.) From conjunctiva.

Micrococcus finlayensis Sternberg. (Rept. on Etiology and Prevention of Yellow Fever, Washington, 1891, 219.) Obtained by Finlay in cultures from the liver and spleen of a yellow-fever cadaver. Hucker (*loc. cit.*, 11) considers this a synonym of *Micrococcus citreus* Migula.

Micrococcus flaccidifex danai Brown. (Amer. Museum Novit., No. 251, 1927, 5.) Causative agent of wilt disease of monarch butterfly larvae (*Danais archippus*). Considered a sub-species of *Gyrococcus flaccidifex* Glaser and Chapman (Science, *36*, 1912, 219).

Micrococcus flagellatus Klotz. (Jour. Med. Research, *11* (N.S.*6*), 1904, 493.) Found in an epizootic among rabbits and white rats. Supposedly flagellated.

Micrococcus flavens Henrici. (Arb. bakt. Inst. Karlsruhe, *1*, Heft 1, 1894, 80.) From Swiss cheese. Winslow and Winslow (*loc. cit.*, 216) consider this a synonym of *Micrococcus flavus* Trevisan.

Micrococcus flavescens Henrici. (Arb. bakt. Inst. Karlsruhe, *1*, Heft 1, 1894, 79.) From Swiss cheese. Winslow and Winslow (*loc. cit.*, 216) consider this a synonym of *Micrococcus flavus* Trevisan. For a description of this species, see Bergey et al., Manual, 5th ed., 1939, 246.

Micrococcus flavidus Henrici. (*loc. cit.*, 81; not *Micrococcus flavidus* Roze, Compt. rend. Acad. Sci., Paris, *122*, 1896, 750.) From Swiss and Limburger cheeses. Winslow and Winslow (*loc. cit.*, 216) consider this a synonym of *Micrococcus flavus* Trevisan.

Micrococcus flavovirens Migula. (*Staphylococcus viridis flavescens* Guttmann, Arch. f. path. Anat., *107*, 1887, 261; *Staphylococcus viridi-flavescens* Trevisan, I generi e le specie delle Batteriacee, Milan, 1889, 33; Migula, Syst. d. Bakt., *2*, 1900, 124; *Micrococcus viridis* Chester, Man. Determ. Bact., 1901, 95; *Micrococcus viridis-flavescens* Winslow and Winslow, Systematic Relationships of the Coccaceae, 1906, 221.) Winslow and Winslow (*ibid.*, 220) consider this a synonym of *Micrococcus luteus* Cohn.

Micrococcus flavus non liquefaciens

Amsler. (Amsler, Korrespondenbl. f. Schweizer Aerzte, 1900, No. 9; Abst. in Cent. f. Bakt., I Abt., *29*, 1901, 450.) From thermal springs.

Micrococcus fluorescens Maggiora. (Giorn. Soc. Ital. d'Igiene, *11*, 1889, 352; Abst. in Cent. f. Bakt., *8*, 1890, 13.) From the skin of the foot.

Micrococcus foetidus Flügge. (Die Mikroorganismen, 2 Aufl., 1886, 172; not *Micrococcus foetidus* Veillon, Compt. rend. Soc. Biol. Paris, 1893, 867; see *Streptococcus foetidus* Prévot.) From carious teeth.

Micrococcus foetidus Klamann. (Allgem. med. Centralzeitung, 1887, 1344.) Isolated from the posterior nares of man. Winslow and Winslow (*loc. cit.*, 199) state that this appears to be a synonym of *Micrococcus albus* Schroeter.

Micrococcus fragilis (Dyar) Migula. (*Merismopedia fragilis* Dyar, Ann. N. Y. Acad. Sci., *8*, 1895, 351; Migula, Syst. d. Bakt., *2*, 1900, 186.) From dust. Hucker (*loc. cit.*, 25) states that this species may be identical with *Micrococcus roseus* Flügge.

Micrococcus franklandiorum Trevisan. (*Micrococcus candicans* Frankland and Frankland, Phil. Trans. Roy. Soc. London, *178*, B, 1888, 270; not *Micrococcus candicans* Flügge, Die Mikroorganismen, 2 Aufl., 1886, 173; Trevisan, I generi e le specie delle Batteriacee, Milan, 1889, 34.) From dust.

Micrococcus fulvus Weiss. (Arb. a. bakt. Inst. Karlsruhe, *2*, Heft 3, 1902, 206; not *Micrococcus fulvus* Cohn, Beitr. z. biol. d. Pflanz., *1*, Heft 3, 1875, 181.) From a bean infusion.

Micrococcus fuscus Adametz. (Brauner Coccus, Maschek, Jahresb. d. Kommunal-Oberrealsch. zu Leitmeritz, No. 6, 1867, 60; Adametz, Bakt. d. Nutz- u. Trinkwässer, Vienna, 1888; *Micrococcus fuscus* Castellani and Chalmers, Man. Trop. Med., 3rd ed., 1919, 932.) Hucker (*loc. cit.*, 10) states that this species is probably identical with *Micrococcus conglomeratus* Migula.

Micrococcus galbanatus Zimmermann. (Bakt. unserer Trink- u. Nutzwässer, Chemnitz, II Reihe, 1894, 68.) From water. Winslow and Winslow (*loc. cit.*, 216) consider this a synonym of *Micrococcus flavus* Trevisan.

Micrococcus gallicidus Burrill. (Amer. Nat., *17*, 1883, 320.) From blood of fowls infected with chicken cholera.

Micrococcus gelatinogenus Bräutigam. (Pharmaceutische Centralhalle, *32*, 1891, 427.) From digitalis infusions. See *Micrococcus gummosus* Happ.

Micrococcus gelatinosus Warrington. (The Lancet, 1, 1888, No. 25; Abst. in Cent. f. Bakt., *4*, 1888, 394.) Curdles milk.

Micrococcus gelatinosus Issatchenko. (Recherches sur les Microbes de l'Océan Glacial Arctique, Petrograd, 1914, 232; not *Micrococcus gelatinosus* Warrington, The Lancet, 1, 1888, No. 25.) From sea water.

Micrococcus giganteus lactis Conn. (Storrs Agr. Exp. Sta. 12th Ann. Rept., 1900, 46.) From milk.

Micrococcus gigas Frankland and Frankland. (Philos. Trans. Roy. Soc., London, *178*, B, 1888, 268.) From dust. Winslow and Winslow (*loc. cit.*, 216) consider this a synonym of *Micrococcus flavus* Trevisan.

Micrococcus gilvus Losski. (Inaug. Diss., Dorpat, 1893, 60.) Winslow and Winslow (*loc. cit.*, 220) consider this a synonym of *Micrococcus luteus* Cohn.

Micrococcus gingivae Migula. (*Micrococcus gingivae pyogenes* Miller, Die Mikroorganismen d. Mundhöhle, Leipzig, 1889, 216; Migula, Syst. d. Bakt., *2*, 1900, 68.) From alveolar pyorrhoea, also from the mouth of a healthy man.

Micrococcus gingreardi Renault. (Compt. rend. Acad. Sci., Paris, *120*, 1895, 217.)

Micrococcus glandulosus Weiss. (Arb. bakt. Inst. Karlsruhe, *2*, Heft 3, 1902, 201.) From an asparagus infusion. Hucker

(*loc. cit.*, 19) regards this species as identical with *Micrococcus freudenreichii* Guillebeau or with *Micrococcus ureae* Cohn.

Micrococcus globosus Kern. (Arb. bakt. Inst. Karlsruhe, *1*, Heft 4, 1897, 469.) From the stomach contents of a coot (*Fulica atra*). Winslow and Winslow (*loc. cit.*, 224) state that this is apparently a synonym of *Micrococcus candicans* Flügge.

Micrococcus granulatus Weiss. (Arb. bakt. Inst. Karlsruhe, *2*, Heft 3, 1902, 197.) From a malt infusion.

Micrococcus granulosus Kern (*loc. cit.*, 483). From the stomach contents of the yellow-hammer (*Emberiza citrinella*) and the starling (*Sturnus vulgaris*). Winslow and Winslow (*loc. cit.*, 220) consider this a synonym of *Micrococcus luteus* Cohn.

Micrococcus griseus (Warming) Winter. (*Bacterium griseum* Warming, Videnskabelige Meddelelser fra den naturhist. Forening i Kjöbenhavn, 1875, 398; Winter, in Rabenhorst, Kryptog.-Flora v. Deutschl., Oesterr. u. d. Schweiz, 2 Aufl., *1*, 1884, 47.)

Micrococcus grossus Henrici. (Arb. bakt. Inst. Karlsruhe, *1*, Heft 1, 1894, 71.) From Camembert cheese. Winslow and Winslow (*loc. cit.*, 224) state that this is apparently a synonym of *Micrococcus candicans* Flügge.

Micrococcus gummosus Happ. (Happ, Inaug. Diss., Basel, 1893, 31; not *Micrococcus gummosus* Weiss, Arb. bakt. Inst. Karlsruhe, *2*, Heft 3, 1902, 189.) From snakeroot and digitalis infusions. Presumably *Leuconostoc mesenteroides* Van Tieghem.

Micrococcus haematodes Zopf. (Microbes de la sueur rouge, Babes, Biol. Centralbl., *2*, 1882, No. 8; Zopf, Die Spaltpilze, 3 Aufl., 1885, 60.) The cause of red perspiration. Hucker (*loc. cit.*, 25) states that this may be a synonym of *Micrococcus roseus* Flügge.

Micrococcus haemorrhagicus (Klein) Migula. (*Staphylococcus haemorrhagicus* Klein, Cent. f. Bakt., I Abt., *22*, 1897, 81; Migula, Syst. d. Bakt., *2*, 1900, 88.) Associated with an erythema of the skin resembling anthrax. Winslow and Winslow (*loc. cit.*, 199) state that this appears to be a synonym of *Micrococcus albus* Schroeter.

Micrococcus halensis Lehmann and Neumann. (*Micrococcus acidi paralactici liquefaciens halensis* Kozai, Ztschr. f. Hyg., *31*, 1899, 374; Lehmann and Neumann, Bakt. Diag., 2 Aufl., *2*, 1899, 210; *Micrococcus acidi paralactici liquefaciens* Thiele, Ztschr. f. Hyg., *46*, 1904, 394.) From milk. Hucker (*loc. cit.*, 17) considers this a synonym of *Micrococcus caseolyticus* Evans.

Micrococcus halophilus Bergey et al. (Culture No. 19, Baranik-Pikowsky, Cent. f. Bakt., II Abt., *70*, 1927, 373; Bergey et al., Manual, 3rd ed., 1930, 89.) From sea water. For a description of this species, see Bergey et al., Manual, 5th ed., 1939, 258.

Micrococcus hauseri (Rosenthal) Migula. (*Diplococcus hauseri* Rosenthal, Inaug. Diss., Berlin, 1893, 26; Migula, *loc. cit.*, 80.) From the oral cavity. Winslow and Winslow (*loc. cit.*, 224) state that this species is apparently identical with *Micrococcus candicans* Flügge.

Micrococcus helvolus Henrici. (Arb. bakt. Inst. Karlsruhe, *1*, Heft 1, 1894, 77.) From Swiss cheese. Winslow and Winslow (*loc. cit.*, 220) consider this to be identical with *Micrococcus luteus* Cohn.

Micrococcus hibiscus Nakahama. (Jour. Agr. Chem. Soc. Japan, *16*, 1940, 345, Eng. Abs., Bull. Agr. Chem. Soc., *16*, 1940, 51.) Isolated from retting kenaf (*Hibiscus*).

Micrococcus humidus Migula. (Micrococcus No. 2, Adametz, Landwirtsch. Jahrb., *18*, 1889, 239; Migula, Syst. d. Bakt., *2*, 1900, 50.) From Emmenthal cheese. Winslow and Winslow (*loc. cit.*, 224) state that this species is apparently identical with *Micrococcus candicans* Flügge.

Micrococcus hydrothermicus Cronquist. (Monatsh. f. prakt. Derm., *36*, 1903.) Optimum temperature 41°C.

Micrococcus hymenophagus Renault. (Compt. rend. Acad. Sci., Paris, *120*, 1895, 217.)

Micrococcus imperatoris Roze. (Compt. rend. Acad. Sci., Paris, *122*, 1896, 545.) Isolated from potatoes. Probably from dust.

Micrococcus inconspicuus Henrici. (Arb. bakt. Inst. Karlsruhe, *1*, Heft 1, 1894, 64.) From Swiss cheese. Winslow and Winslow (*loc. cit.*, 224) state that this species is apparently identical with *Micrococcus candicans* Flügge.

Micrococcus indolicus Christiansen. (Ac. Path. Micr. Scand., *18*, 1934, 42; *Staphylococcus asaccharolyticus* var. *indolicus* Weinberg, Nativelle and Prévot, Les Microbes Anaérobies, 1937, 1023.) Strict anaerobe. For description see Bergey et al., Manual, 5th ed., 1939, 266.

Micrococcus influenzae Migula. (Mikroorganismus II, Fischel, Ztschr. f. Heilkunde, *12*, 1891; Abst. in Cent. f. Bakt., *9*, 1891, 611; Migula, Syst. d. Bakt., *2*, 1900, 90.) From the blood of an influenza patient. Winslow and Winslow (*loc. cit.*, 199) state that this appears to be identical with *Micrococcus albus* Schroeter.

Micrococcus insectorum Burrill. (Burrill, Amer. Nat., *17*, 1883, 319; *Streptococcus insectorum* De Toni and Trevisan, in Saccardo, Sylloge Fungorum, *8*, 1889, 1061; *Bacillus insectorum* Smith, 28th Biennial Rept. Kan. State Bd. Agri., 1933, 54.) From the cecal organs of the chinch bug (*Blissus leucopterus*).

Micrococcus intermedius Stark and Scheib. (Jour. Dairy Sci., *19*, 1936, 210.) From butter.

Micrococcus intertriginis Meyer. (N.Y. Med. Jour., *70*, 1900, 873; Abst. in Cent. f. Bakt., I Abt., *30*, 1901, 434.) From a case of erythema intertrigo.

Micrococcus iris Henrici. (Arb. bakt. Inst. Karlsruhe, *1*, Heft 1, 1894, 67.) From Limburger cheese. Winslow and Winslow (*loc. cit.*, 224) state that this species is apparently identical with *Micrococcus candicans* Flügge.

Micrococcus irregularis Weiss. (Arb. bakt. Inst. Karlsruhe, *2*, Heft 3, 1902, 184.) From an infusion of beans and carrots.

Micrococcus jongii Chester. (*Staphylococcus pyogenes bovis* de Jong, Cent. f. Bakt., I Abt., *25*, 1899, 64; *Staphylococcus bovis* de Jong, *ibid.*, 67; Chester, Man. Determ. Bact., 1901, 95.) Associated with suppurative processes in cattle. Winslow and Winslow (*loc. cit.*, 220) consider this a synonym of *Micrococcus luteus* Cohn.

Micrococcus lactericeus Freund. (Inaug. Diss., Erlangen, 1893, 21; Abst. in Cent. f. Bakt., *16*, 1894, 640.) From the human mouth. Hucker (*loc. cit.*, 21) regards this as a synonym of *Micrococcus candidus* Cohn or of *Micrococcus epidermidis* Hucker.

Micrococcus lacteus Henrici. (Arb. bakt. Inst. Karlsruhe, *1*, Heft 1, 1894, 74.) From cheese. Winslow and Winslow (*loc. cit.*, 199) state that this appears to be a synonym of *Micrococcus albus* Schroeter; while Hucker (*loc. cit.*, 19) considers it a synonym of *Micrococcus freudenreichii* Guillebeau or of *Micrococcus ureae* Cohn.

Micrococcus lactis Chester. (No. 44, Conn, Storrs Agr. Exp. Sta., 7th Ann. Rept., 1895, 79; Chester, Man. Determ. Bact., 1901, 90.) From milk. Winslow and Winslow (*loc. cit.*, 224) state that this is apparently a synonym of *Micrococcus candicans* Flügge.

Micrococcus lactis II (Hueppe) Scholl. (Quoted from Löhnis, Cent. f. Bakt., II Abt., *18*, 1907, 141.) From milk.

Micrococcus lactis acidi Krueger. (Cent. f. Bakt., *7*, 1890, 494.) From milk.

Micrococcus lactis albus Conn, Esten and Stocking. (Storrs Agr. Exp. Sta. 18th Ann. Rept., 1907, 120.) From milk. Hucker (*loc. cit.*, 19) considers this a synonym of *Micrococcus freudenreichii*

Guillebeau or of *Micrococcus ureae* Cohn.

Micrococcus lactis amari von Freudenreich. (Bittere Milch *Micrococcus*, Conn, Cent. f. Bakt., *9*, 1891, 653; von Freudenreich, Cent. f. Bakt., II Abt., *13*, 1904, 407.) From the udder and bitter cream.

Micrococcus lactis aureus Conn, Esten and Stocking (*loc. cit.*, 112). From milk, butter, cheese, stable dust. Hucker (*loc. cit.*, 7 and 12) regards this as a synonym of *Micrococcus luteus* Cohn, of *Micrococcus varians* Migula or of *Micrococcus aureus* Zopf.

Micrococcus lactis citreus Conn, Esten and Stocking (*loc. cit.*, 102). From milk. Hucker (*loc. cit.*, 7) considers this species identical with *Micrococcus luteus* Cohn or with *Micrococcus varians* Migula.

Micrococcus lactis citronus Conn, Esten and Stocking (*loc. cit.*, 117). From slime on Camembert cheese. Hucker (*loc. cit.*, 12) regards this as a synonym of *Micrococcus aureus* Zopf.

Micrococcus lactis flavus Conn, Esten and Stocking (*loc. cit.*, 109). May be identical with *Micrococcus aurantiacus* Cohn. From milk. Hucker (*loc. cit.*, 7 and 12) states that this may be a synonym of *Micrococcus luteus* Cohn, of *Micrococcus varians* Migula or of *Micrococcus aureus* Zopf.

Micrococcus lactis fluorescens Conn, Esten and Stocking (*loc. cit.*, 120). From stable dust. Exhibits a green fluorescence. Hucker (*loc. cit.*, 18) states that this species is very similar to *Micrococcus caseolyticus* Evans.

Micrococcus lactis gigas Conn, Esten and Stocking (*loc. cit.*, 116). From milk. Hucker (*loc. cit.*, 22) states that this species is probably identical with *Micrococcus candidus* Cohn or *Micrococcus epidermidis* Hucker.

Micrococcus lactis giganteus Conn, Esten and Stocking (*loc. cit.*, 122). From milk.

Micrococcus lactis minutissimus Conn, Esten and Stocking (*loc. cit.*, 119). From milk. Hucker (*loc. cit.*, 10) considers this a synonym of *Micrococcus conglomeratus* Migula.

Micrococcus lactis rosaceus Conn, Esten and Stocking (*loc. cit.*, 109). From milk. Hucker (*loc. cit.*, 26) states that this is probably identical with *Micrococcus roseus* Flügge.

Micrococcus lactis rugosus Conn, Esten and Stocking (*loc. cit.*, 122). From milk.

Micrococcus lactis varians Conn, Esten and Stocking (*loc. cit.*, 121). Commonly found in milk. May be identical with *Micrococcus aureus* Zopf. Hucker (*loc. cit.*, 15) states that this may be identical in part with *Micrococcus albus* Schroeter.

Micrococcus lardarius Krassilschtschik. (Memoires Soc. Zool. de France, *9*, 1896, 513; Compt. rend. Acad. Sci., Paris, *123*, 1896, 428.) From diseased silkworms. Differs from *Streptococcus bombycis*. Hucker (*loc. cit.*, 22) states that this is probably identical with either *Micrococcus candidus* Cohn or *Micrococcus epidermidis* Hucker.

Micrococcus lembkei Migula. (No. 21, Lembke, Arch. f. Hyg., *29*, 1897, 327; Migula, Syst. d. Bakt., *2*, 1900, 212.) From feces. Winslow and Winslow (*loc. cit.*, 220) consider this a synonym of *Micrococcus luteus* Cohn, while Hucker (*loc. cit.*, 11) regards it as probably identical with *Micrococcus citreus* Schroeter.

Micrococcus lentus Migula. (No. 22, Lembke, *loc. cit.*, 328; Migula, *loc. cit.*, 209.) From feces. Winslow and Winslow (*loc. cit.*, 199) state that this appears to be a synonym of *Micrococcus albus* Schroeter; while Hucker (*loc. cit.*, 19) regards it as probably identical with *Micrococcus freudenreichii* Guillebeau or *Micrococcus ureae* Cohn.

Micrococcus licheniformis Kern. (Arb. bakt. Inst. Karlsruhe, *1*, Heft 4, 1897, 482.) From the intestine of the yellowhammer (*Emberiza citrinella*). Winslow and Winslow (*loc. cit.*, 220) consider this a synonym of *Micrococcus luteus* Cohn.

Micrococcus lignithum Renault.

(Compt. rend. Acad. Sci., Paris, *126*, 1898, 1828.) A fossil form from lignite.

Micrococcus lipolyticus Horowitz-Wlassowa. (Ztschr. f. Untersuch. d. Lebensmittel, *62*, 1931, 602.) A fat splitting micrococcus from salted fish.

Micrococcus lipolyticus Stark and Scheib. (Jour. Dairy Sci., *19*, 1936, 210; not *Micrococcus lipolyticus* Horowitz-Wlassowa, *loc. cit.*) From butter.

Micrococcus liquefaciens Migula. (*Micrococcus ureae liquefaciens* Flügge, Die Mikroorganismen, 2 Aufl., 1886, 169; *Streptococcus aëthebius* Trevisan, I generi e le specie delle Batteriacee, Milan, 1889, 31; *Staphylococcus ureae liquefaciens* Lundström, Festschr. d. path. anat. Inst. z. Andenken a.d. 250 jährige Bestehen d. finnländ. Univ. z. Helsingfors, 1890; abst. in Cent. f. Bakt., *9*, 1891, 672; Migula, Syst. d. Bakt., *2*, 1900, 106; *Micrococcus aethebius* Chester, Man. Determ. Bact., 1901, 77; *Urococcus liquefaciens flueggei* Miquel and Cambier, Traité de Bact., 1902, 627; *Micrococcus liquefaciens flueggei* Miquel in Lafar, Handb. d. tech. Mykol., *3*, 1904–06, 75; *Albococcus ureae* Kligler, Jour. Inf. Dis., *12*, 1913, 442; not *Micrococcus liquefaciens* Bergey et al., Manual, 1st ed., 1923, 67.) From urine. Hucker (*loc. cit.*, 18 and 19) states that this species may be identical with *Micrococcus caseolyticus* Evans, *Micrococcus freudenreichii* Guillebeau or *Micrococcus ureae* Cohn.

Micrococcus liquefaciens acidi I and *II*, Conn. (Storrs Agr. Exp. Sta. 12th Ann. Rept., 1900, 48.) From milk. Hucker (*loc. cit.*, 18) regards this species as very similar to *Micrococcus caseolyticus* Evans.

Micrococcus liquidus Migula. (No. 21, Lembke, Arch. f. Hyg., *26*, 1896, 313; Migula, Syst. d. Bakt., *2*, 1900, 208.) From feces. Hucker (*loc. cit.*, 15) states that this species appears identical with *Micrococcus albus* Schroeter.

Micrococcus lobatus Migula. (Siebert, Inaug. Diss., Würzburg, 1894, No. 3, 10; Migula, Syst. d. Bakt., *2*, 1900, 139.) From the human scalp. Winslow and Winslow (*loc. cit.*, 184) state that this is apparently a synonym of *Micrococcus aureus* Zopf.

Micrococcus loewenbergii Trevisan. (Micrococcus de l'ozène, Löwenberg, Congrès des otologistes, 1884 and Union médicale, 1884; Trevisan, I generi e le specie delle Batteriacee, Milan, 1889, 33.) From secretions in ozena.

Micrococcus luridus Kern. (Arb. bakt. Inst. Karlsruhe, *1*, Heft, 4, 1897, 480.) From the intestine of the chaffinch (*Fringilla coelebs*). Winslow and Winslow (*loc. cit.*, 220) consider this a synonym of *Micrococcus luteus* Cohn.

Micrococcus luteolus Henrici. (Arb. bakt. Inst. Karlsruhe, *1*, Heft 1, 1894, 82; not *Micrococcus luteolus* Irwin and Harrison, Le Lait, *8*, 1928, 881.) From cheese. Winslow and Winslow (*loc. cit.*, 216) consider this a synonym of *Micrococcus flavus* Trevisan. For a description of Irwin and Harrison's organism, see Bergey et al., Manual, 5th ed., 1939, 249.)

Micrococcus luteus var. *larvae* Hauduroy et al. (*Micrococcus luteus-liquefaciens* var. *larvae* Toumanoff, Bull. Soc. Centr. de Méd. Vétér., *80*, 1927, 367; Hauduroy et al., Dict. d. Bact. Path., 1937, 277.) From foulbrood of bees. Pathogenic.

Micrococcus lutosus Kern. (Arb. bakt. Inst. Karlsruhe, *1*, Heft 4, 1897, 489.) From the stomach contents of the chaffinch (*Fringilla coelebs*). Winslow and Winslow (*loc. cit.*, 216) consider this a synonym of *Micrococcus flavus* Trevisan.

Micrococcus lysodeikticus Fleming. (Proc. Roy. Soc. London, Ser. B, *93*, 1922, 306.) Non-pathogenic.

Micrococcus lyssae (Rivolta) Trevisan. (*Cocco-bacterium lyssae* Rivolta, 1886; Trevisan, I generi e le specie delle Batteriacee, Milan, 1889, 33.) Spore-bearer.

Micrococcus madidus Migula. (No. 19, Lembke, Arch. f. Hyg., *26*, 1896, 311; Migula, Syst. d. Bakt., *2*, 1900, 207.) From feces. Winslow and Winslow (*loc. cit.*, 184) state that this is apparently a synonym of *Micrococcus aureus* Migula;

while Hucker (*loc. cit.*, 15) regards it as identical with *Micrococcus albus* Schroeter.

Micrococcus magnus (Miller) Trevisan. (*Jodococcus magnus* Miller, Deutsche med. Wochnschr., No. 30, 1888; Trevisan, I generi e le specie delle Batteriacee, Milan, 1889, 33; not *Micrococcus magnus* Chester, Man. Determ. Bact., 1901, 85 (*Diplococcus magnus* Rosenthal, Cent. f. Bakt., *25*, 1899, 1); not *Micrococcus magnus* Stark and Scheib, Jour. Dairy Sci., *19*, 1936, 210.)

Micrococcus major De Toni and Trevisan. (*Micrococcus urinae major* Doyen, Jour. d. connaiss. médic., No. 14, 1889, 108; De Toni and Trevisan, in Saccardo, Sylloge Fungorum, *8*, 1889, 1076.) From urine.

Micrococcus major Eckstein. (Ztschr. f. Forst- u. Jagdwesen, *26*, 1894, 18; not *Micrococcus major* DeToni and Trevisan, in Saccardo, Sylloge Fungorum, *8*, 1889, 1076.) Isolated from the larvae of the nun moth (*Lymantria monacha*) and *Hyponomeuta sp.*

Micrococcus manfredii Trevisan. (Micrococcus der progressiven Lymphome im Tierörper, Manfredi, Fortschr. d. Med., 1886, 713; Trevisan, I generi e le specie delle Batteriacee, Milan, 1889, 33; *Streptococcus manfredii* DeToni and Trevisan, in Saccardo, Sylloge Fungorum, *8*, 1889, 1056; *Micrococcus canus* Migula, Syst. d. Bakt., *2*, 1900, 63.) From sputum. Winslow and Winslow (*loc. cit.*, 206) regard this as a synonym of *Micrococcus candidus* Cohn or of *Gaffkya tetragena* Trevisan.

Micrococcus malolacticus Seifert. (Ztschr. f. d. landwirtsch. Versuchswesen in Oesterreich, 1903, 567; Abst. in Cent. f. Bakt., II Abt., *10*, 1903, 664.) From wine. Hucker (*loc. cit.*, 7) considers this a synonym of *Micrococcus luteus* Cohn or of *Micrococcus varians* Migula.

Micrococcus mammitis Hutchens. (Hutchens in Besson, Pract. Bact. Microbiol. and Serum Therapy, Trans. of 5th ed., 1913, 615; not *Streptococcus mammitis bovis* Hutchens, *ibid.*, 613.) From gangrenous mammitis of milking ewes. This is le microcoque de l'araignée or de la mammite gangréneuse, Nocard, Ann. Inst. Past., *1*, 1887, 417.

Micrococcus marginatus Wilhelmy. (Arb. bakt. Inst. Karlsruhe, *3*, 1903, 11.) From meat extract.

Micrococcus marinus Issatchenko. (Recherches sur les Microbes de l'Océan Glacial Arctique, Petrograd, 1914, 147.) From sea water.

Micrococcus mastitidis Holland. (Jour. Bact., *5*, 1920, 224.) *Nomen nudum.*

Micrococcus mastobius Trevisan. (Micrococque de la mammite gangréneuse des brebis laitières, Nocard, Ann. Inst. Past., *1*, 1887, 417; Trevisan, I generi e le specie delle Batteriacee, Milan, 1889, 33; *Micrococcus gangr. ovium*, quoted from Freire, Rio de Janeiro, 1898; Abst. in Cent. f. Bakt., I Abt., *26*, 1899, 841; *Micrococcus ovis* Migula, Syst. d. Bakt., *2*, 1900, 90; *Micrococcus mastitis* Chester, Man. Determ. Bact., 1901, 76; *Micrococcus mastidis gangraenosae ovis* Pfeiler, Ztschr. f. Infektionskr., parasit. Krankh. u. Hyg. d. Haustiere, *4*, 1908, 132.) Said to be the cause of gangrenous mastitis in sheep. This species appears to be *Micrococcus pyogenes* Migula.

Micrococcus melanocyclus Merker. (Cent. f. Bakt., II Abt., *41*, 1911, 589.) See *Actinomyces melanocyclus* Krainsky.

Micrococcus melanoglossophorus Spegazzini. (Fung. Arg. Pug., *4*, 18--, 316.) From the epithelium of the tongue.

Micrococcus meldensis Roger. (Ber. An. de Soc. d'Agric. de Meaux, 1898.)

Micrococcus melleus grandinis Harrison. (Bot. Gazette, *26*, 1898, 211.)

Micrococcus memelensis Leichmann. (Coccus, Leichmann, Cent. f. Bakt., II Abt., *2*, 1896, 780; Leichmann, in Koch, Jahresber., *12*, 1901, 254; *Micrococcus acidi laevolactici* Weigmann, in Lafar, Handb. d. techn. Mykol., *2*, 1905, 62.) From milk.

Micrococcus minimus Weiss. (Arb. bakt. Inst. Karlsruhe, *2*, Heft 3, 1902,

188; not *Micrococcus minimus* Bergey et al., Manual, 1st ed., 1923, 69.) From a bean infusion. Hucker (*loc. cit.*, 7) considers this a synonym of either *Micrococcus luteus* Cohn or *Micrococcus varians* Migula.

Micrococcus minutissimus Issatchenko. (Recherches sur les Microbes de l'Océan Glacial Artique, Petrograd, 1914, 146.) From sea water.

Micrococcus mirificus (Rabenhorst) Trevisan. (*Palmella mirifica* Rabenhorst, Hedwigia, 1867, 115, and Flor. Europ. Algar., *3*, 1856, 35; Trevisan, Rendic. R. Ist. Lombardo, *12*, 1879.)

Micrococcus mollis (Dyar) Migula. (*Merismopedia mollis* Dyar, Ann. N. Y. Acad. Sci., *8*, 1895, 352; Migula, Syst. d. Bakt., *2*, 1900, 161; *Aurococcus mollis* Winslow and Rogers, Science, *21*, 1905, 669; *Staphylococcus mollis* Holland, Jour. Bact., *5*, 1920, 225.) From air. A cause of boils in the tropics, according to Castellani and Chalmers (Man. Trop. Med., 3rd ed., 1919, 931). Hucker (*loc. cit.*, 12) states that this species is apparently identical with *Micrococcus aureus* Zopf.

Micrococcus (*Diplococcus*) *morrhuae* Klebahn. (Mitteil. Inst. Allgm. Botan. Hamburg, *4*, 1919, 11-69; Abst. in Cent. f. Bakt., II Abt., *52*, 1921, 123.) Halophilic. Associated with spoilage of salted fish.

Micrococcus mucilagineus Weiss. (Arb. bakt. Inst. Karlsruhe, *2*, Heft 3, 1902, 191.) From bean infusions. Hucker (*loc. cit.*, 11) states that this is probably a synonym of *Micrococcus citreus* Migula.

Micrococcus mucilaginosus Migula. (Micrococcus der schleimigen Milch, Ratz, Arch. f. Tierheilkunde, *12*, Heft 1 and 2, 1890; Migula, Syst. d. Bakt., *2*, 1900, 119; not *Micrococcus mucilaginosus* Weiss, Arb. bakt. Inst. Karlsruhe, *2*, Heft 3, 1902, 205.) From slimy milk. Winslow and Winslow (*loc. cit.*, 199) state that this appears to be a synonym of *Micrococcus albus* Schroeter; while Hucker (*loc. cit.*, 18) considers it a synonym in part of *Micrococcus caseolyticus* Evans.

Micrococcus mucofaciens Thöni and Thaysen. (Cent. f. Bakt., II Abt., *36*, 1913, 359; not *Micrococcus mucofaciens* Pribram, Klassifikation der Schizomyceten, 1933, 42.) From milk. Hucker (*loc. cit.*, 9) considers this a synonym of *Micrococcus flavus* Trevisan. For a description of this species, see Bergey et al., Manual, 5th ed., 1939, 245.

Micrococcus myceticus Castellani. (Proc. Soc. Exp. Biol. and Med., *25*, 1928, 535–536.) From gummy lesions.

Micrococcus mycodermatus Holland. (Jour. Bact., *5*, 1920, 224.)

Micrococcus nacreaceus Migula. (Perlmutterglänzender Diplococcus, Tataroff, Inaug. Diss., Dorpat, 1891, 70; Migula, Syst. d. Bakt., *2*, 1900, 62.) Winslow and Winslow (*loc. cit.*, 224) state that this is apparently a synonym of *Micrococcus candicans* Flügge.

Micrococcus neoformans Doyen. (Doyen, Le *Micrococcus neoformans* et les néoplasmes, Paris, 1903.) From cancerous tissue. Shown by Andrewes and Gordon (35th Ann. Rept. Local Govt. Board, London, 1905–06, 553) to be identical with *Micrococcus epidermidis albus* Welch.

Micrococcus neurotomae Paillot. (Compt. rend. Acad. Sci., Paris, *178*, 1924, 246.) Gram-negative. From the larvae of *Neurotoma nemoralis*.

Micrococcus neuvillei Trevisan. (Micrococcus G, Malapert-Neuville, 1887; Trevisan, I generi e le specie delle Batteriacee, Milan, 1889, 34.) From mineral water.

Micrococcus nigrescens Castellani. (Brit. Jour. of Dermatology, *23*, 1911, 341; *Nigrococcus nigrescens* Castellani and Chalmers, Man. Trop. Med., 3rd ed., 1919, 2103.) Produces a black pigment. Found in the black variety of trichomycosis axillaris, a tropical disease.

Micrococcus nigrofaciens Northrup. (Mich. Agr. Exp. Sta. Tech. Bull. No. 18, 1914, 12; also in Cent. f. Bakt., II Abt.,

41, 1914, 326.) From diseased larvae of the June beetle (*Lachnosterna sp.*) and other insects.

Micrococcus nitidus Kern. (Arb. bakt. Inst. Karlsruhe, *1*, Heft 4, 1897, 476.) From the stomach and intestine of birds. Winslow and Winslow (*loc. cit.*, 199) state that this appears to be a synonym of *Micrococcus albus* Schroeter; while Hucker (*loc. cit.*, 19) regards it as a synonym of *Micrococcus freudenreichii* Guillebeau or of *Micrococcus ureae* Cohn.

Micrococcus nitrificans Bergey et al. (Micrococcus 6, Rubentschick, Cent. f. Bakt., II Abt., *72*, 1927, 125; Bergey et al., Manual, 3rd ed., 1930, 88; not *Micrococcus nitrificans* van Tieghem, Traité de Botanique, Paris, 1883.) From sewage filter beds. For a description of this species, see Bergey et al., Manual, 5th ed., 1939, 257.

Micrococcus nivalis Chester. (No. 47, Conn, Storrs Agr. Exp. Sta. 7th Ann. Rept., 1895, 80; Chester, Man. Determ. Bact., 1901, 90.) From dust. Winslow and Winslow (*loc. cit.*, 224) state that this is apparently a synonym of *Micrococcus candicans* Flügge.

Micrococcus niveus Henrici. (Arb. bakt. Inst. Karlsruhe, *1*, Heft 1, 1894, 66.) From Swiss cheese. Winslow and Winslow (*loc. cit.*, 224) state that this is apparently a synonym of *Micrococcus candicans* Flügge.

Micrococcus nonfermentans Steinhaus. (Jour. Bact., *42*, 1941, 779.) From the alimentary tract of the lyreman cicada (*Tibicen linnei*) and of an unidentified damsel fly (*Coenagrionidae*).

Micrococcus nubilis Migula. (Coccus B, Foutin, Bakt. Untersuch. von Hagel, Wratsch, No. 49 and 50, 1889; see Cent. f. Bakt., *7*, 1890, 373; Migula, Syst. d. Bakt., *2*, 1900, 60; *Micrococcus beta* Chester, Man. Determ. Bact., 1901, 87.) Isolated from hail. Winslow and Winslow (*loc. cit.*, 205) consider this to be a synonym of *Micrococcus candidus* Cohn or of *Gaffkya tetragena* Trevisan.

Micrococcus nuclei Roze. (Compt. rend. Acad. Sci., Paris, *122*, 1896, 544.) From potatoes.

Micrococcus obscoenus Kern. (Arb. bakt. Inst. Karlsruhe, *1*, Heft 4, 1897, 473.) From the stomach contents of a crow (*Corvus corone*). Winslow and Winslow (*loc. cit.*, 199) state that this appears to be a synonym of *Micrococcus albus* Schroeter; while Hucker (*loc. cit.*, 19) considers it a synonym of *Micrococcus freudenreichii* Guillebeau or of *Micrococcus ureae* Cohn.

Micrococcus ochraceus Rosenthal. (Inaug. Diss., Erlangen, 1893, 22; Abst. in Cent. f. Bakt., *16*, 1894, 1024; not *Micrococcus ochraceus* Hansgirg, Oestr. Bot. Ztschr., 1885, No. 4.) From the oral cavity. Winslow and Winslow (*loc. cit.*, 220) consider this a synonym of *Micrococcus luteus* Migula. For a description of this species see Bergey et al., Manual, 5th ed., 1939, 242.

Micrococcus ochroleucus Prove. (Prove, Beitr. z. Biol. d. Pflanz., *4*, Heft 3, 1887, 409; *Streptococcus ochroleucus* Trevisan, I generi e le specie delle Batteriacee, Milan, 1889, 31; *Planococcus ochroleucus* Migula, Syst. d. Bakt., *2*, 1900, 272.) From urine. Motile.

Micrococcus odoratus Henrici. (Arb. bakt. Inst. Karlsruhe, *1*, Heft 1, 1894, 73.) From cheese. Winslow and Winslow (*loc. cit.*, 224) state that this is apparently a synonym of *Micrococcus candicans* Flügge.

Micrococcus odorus Henrici (*loc. cit.*, 72). From cheese. Winslow and Winslow (*loc. cit.*, 224) state that this species is apparently a synonym of *Micrococcus candicans* Flügge.

Micrococcus olearius DeToni and Trevisan. (*Micrococcus urinae flavus olearius* Doyen, Jour. d. connaiss. Médic., No. 14, 1889, 108; DeToni and Trevisan, in Saccardo, Sylloge Fungorum, *8*, 1889, 1077.) From urine. Hucker (*loc. cit.*, 12) considers this species a synonym of *Micrococcus aureus* Zopf.

Micrococcus olens Henrici. (Arb. bakt. Inst. Karlsruhe, *1*, Heft 1, 1894, 87.)

From Swiss cheese. Winslow and Winslow (*loc. cit.*, 216) consider this a synonym of *Micrococcus flavus* Trevisan.

Micrococcus opalescens DeToni and Trevisan. (*Micrococcus albus II*, Maggiora, Giorn. Soc. Ital. d'Igiene, *11*, 1889, 351; DeToni and Trevisan, in Saccardo, Sylloge Fungorum, *8*, 1889, 1078.)

Micrococcus orbicularis Chester. (*Micrococcus orbicularis flavus* Ravenel, Mem. Nat. Acad. Sci., *8*, 1896, 8; Chester, Man. Determ. Bact., 1901, 101.) From soil. Winslow and Winslow (*loc. cit.*, 216) consider this a synonym of *Micrococcus flavus* Trevisan; while Hucker (*loc. cit.*, 10) regards it as a synonym of *Micrococcus conglomeratus* Migula.

Micrococcus orbiculatus Wright. (Mem. Nat. Acad. Sci., *7*, 1895, 432.) From Schuylkill River water. Winslow and Winslow (*loc. cit.*, 220) consider this a synonym of *Micrococcus luteus* Cohn.

Micrococcus ovalis Kern. (Arb. bakt. Inst. Karlsruhe, *1*, Heft 4, 1897, 500; not *Micrococcus ovalis* Escherich, Die Darmbakterien des Säuglings, Stuttgart, 1886, 90.) From the stomach contents of the rock dove (*Columba livia*). Hucker (*loc. cit.*, 9) regards this as a synonym of *Micrococcus flavus* Trevisan.

Micrococcus pallens Henrici. (Arb. bakt. Inst. Karlsruhe, *1*, Heft 1, 1894, 61.) From cheese. Winslow and Winslow (*loc. cit.*, 205) consider this a synonym of *Micrococcus candidus* Cohn or of *Gaffkya tetragena* Trevisan.

Micrococcus pallidus Henrici (*loc. cit.*, 62). From cheese. Hucker (*loc. cit.*, 7) regards this species as identical with either *Micrococcus luteus* Cohn or *Micrococcus varians* Migula.

Micrococcus pannosus Kern. (Arb. bakt. Inst. Karlsruhe, *1*, Heft 4, 1897, 466.) From the stomach contents of the rock dove (*Columba livia*) and the intestine of another dove (*Columba oenas*). Winslow and Winslow (*loc. cit.*, 224) state that this is apparently a synonym of *Micrococcus candicans* Flügge.

Micrococcus paraffinae Söhngen. (Cent. f. Bakt., II Abt., *37*, 1913, 595.) From garden earth.

Micrococcus parotitidis Korentschewsky. (Cent. f. Bakt., I Abt., Orig., *44*, 1907, 402.) Isolated from cases of parotitis epidemica.

Micrococcus parvus (Miller) Trevisan. (*Jodococcus parvus* Miller, Deutsche med. Wchnschr., No. 30, 1888; Trevisan, I generi e le specie delle Batteriacee, Milan, 1889, 33.)

Micrococcus parvus Migula. (No. 14, Lembke, Arch. f. Hyg., *26*, 1896, 309; Migula, Syst. d. Bakt., *2*, 1900, 200.) From feces. Winslow and Winslow (*loc. cit.*, 224) state that this species is apparently a synonym of *Micrococcus candicans* Flügge.

Micrococcus pasteuri Trevisan. (Microbe pyogene de l'eau de Seine, Pasteur, 1877; Trevisan, I generi e le specie delle Batteriacee, Milan, 1889, 34; not *Micrococcus pasteuri* Sternberg, Trans. Pathol. Soc. of Philadelphia, *12*, 1885, 162.) From water.

Micrococcus pellucidus Kern. (Arb. bakt. Inst. Karlsruhe, *1*, Heft 4, 1897, 468; not *Micrococcus pellucidus* Roze, Compt. rend. Acad. Sci., Paris, *122*, 1896, 1012.) From the intestine of a sparrow (*Passer montanus*). Hucker (*loc. cit.*, 23) regards this as a synonym of *Micrococcus candidus* Cohn or of *Micrococcus epidermidis* Hucker.

Micrococcus pemphigi Migula. (Diplococcus des Pemphigus acutus, Demme, Verhandl. d. Kongr. f. innere Med., Wiesbaden, 1886, 336; *Diplococcus pemphigi acuti* Lehmann and Neumann, Bakt. Diag., 1 Aufl., *2*, 1896, 173; Migula, Syst. d. Bakt., *2*, 1900, V and 191; *Micrococcus demmei* Chester, Man. Determ. Bact., 1901, 74.) Isolated from bullae in a case of pemphigus acutus.

Micrococcus pemphigicontagiosi Castellani and Chalmers. (*Micrococcus pemphigi contagiosa* Clegg and Wherry, Jour. Inf. Dis., *3*, 1906, 171; Castellani and Chalmers, Man. Trop. Med., 3rd ed., 1919, 931.) From bullae in a case of pem-

phigus contagiosa. This may be a synonym of *Micrococcus pemphigineonatorum*, see below.

Micrococcus pemphigineonatorum Castellani and Chalmers. (*Micrococcus pemphigi neonatorum* Almquist, Ztschr. f. Hyg., *10*, 1891, 253; *Staphylococcus pemphigi neonatorum* Lehmann and Neumann, Bakt. Diag., 1 Aufl., *2*, 1896, 173; Castellani and Chalmers, Man. Trop. Med., 3rd ed., 1919, 931.) Found in bullae in a case of pemphigus neonatorum. This may be *Micrococcus mollis*, according to Castellani and Chalmers (*loc. cit.*). Falls (Jour. Inf. Dis., *20*, 1917, 97) identifies this and the previous organism as *Micrococcus pyogenes* var. *aureus* Zopf.

Micrococcus percitreus Bergey et al. (Manual, 1st ed., 1923, 63.) From air and water. Hucker (*loc. cit.*, 10) considers this a synonym of *Micrococcus conglomeratus* Migula. For a description of this species, see Bergey et al., Manual, 5th ed., 1939, 248.

Micrococcus perflavus Bergey et al. (Manual, 1st ed., 1923, 62.) From air and water. Hucker (*loc. cit.*, 12) regards this as a synonym of *Micrococcus aureus* Zopf. For a description of this species, see Bergey et al., Manual, 5th ed., 1939, 247.

Micrococcus persicus Kern. (Arb. bakt. Inst. Karlsruhe, *1*, Heft 4, 1897, 499.) From the intestine of a dove (*Columba oenas*). Hucker (*loc. cit.*, 25) states that this may be identical with *Micrococcus roseus* Flügge.

Micrococcus petechialis Trevisan. (Micrococco del dermotifo, Bareggi, 1886; Trevisan, I generi e le specie delle Batteriacee, Milan, 1889, 33.)

Micrococcus petilus Trevisan. (Micrococcus der Pyaemie bei Kaninchen, Koch, Über d. Aetiolog. d. Wundinfectionskr., Leipzig, 1878; *Micrococcus pyaemiae cuniculorum* Schroeter, in Cohn, Kryptogam. Flora v. Schlesien, *3*, 1, 1886, 148; Trevisan, I generi e le specie delle Batteriacee, Milan, 1889, 33; *Micrococcus cuniculorum* Migula, Syst. d. Bakt., *2*, 1900, 192.) From rabbits.

Micrococcus petrolei Renault. (Compt. rend. Acad. Sci., Paris, *124*, 1897, 1315.) A fossil form from oil bearing rocks.

Micrococcus pieridis Burrill. (Quoted from Chittenden, U. S. Dept. Agr., Farmers' Bull. No. 1461, 1926, 6.) From larvae of the cabbage butterfly (*Pieris rapae*).

Micrococcus pikowskyi Bergey et al. (Culture No. 22, Baranik-Pikowsky, Cent. f. Bakt., II Abt., *70*, 1927, 373; Bergey et al., Manual, 3rd ed., 1930, 78.) From sea water. For a description of this species, see Bergey et al., Manual, 5th ed., 1939, 242.

Micrococcus piliformis Weiss. (Arb. bakt. Inst. Karlsruhe, *2*, Heft 3, 1902, 194.) From a bean infusion. Hucker (*loc. cit.*, 7) considers this a synonym of *Micrococcus luteus* Cohn or of *Micrococcus varians* Migula.

Micrococcus piltonensis Gray and Thornton. (Cent. f. Bakt., II Abt., *73*, 1928, 81.) From manure and soil. For a description of this species, see Bergey et al., Manual, 5th ed., 1939, 259.

Micrococcus pituitoparus (Hohl) Buchanan and Hammer. (*Karphococcus* (*Carphococcus*) *pituitoparus* Hohl, Jahrb. d. Schweiz, *22*, 1906, 439; *Diplococcus viscosus* Sato, Cent. f. Bakt., II Abt., *19*, 1907, 27; Buchanan and Hammer, Iowa Agr. Exp. Sta. Res. Bull. 22, 1915, 285.) From slimy milk and from straw. Hucker (*loc. cit.*, 23) states that this species is probably identical with *Micrococcus candidus* Cohn or with *Micrococcus epidermidis* Hucker. For a description of this species, see Bergey et al., Manual, 5th ed., 1939, 243.

Micrococcus plumosus Eisenberg. (Bräutigam, Inaug. Diss., Leipzig, 1886, 18; Federiger Micrococcus, Adametz, Mitteil. d. Oesterr. Versuchssta. f. Brauerei u. Mälzerei, Wien, Heft 1, 1888; Eisenberg, Bakt. Diag., 3 Aufl., 1891, 56.) From feces of cattle and from water. Winslow and Winslow (*loc. cit.*,

220) consider this a synonym of *Micrococcus luteus* Cohn; while Hucker (*loc. cit.*, 22 and 23) regards it as probably identical with *Micrococcus candidus* Cohn or *Micrococcus epidermidis* Hucker.

Micrococcus polypus Migula. (Syst. d. Bakt., *2*, 1900, 79.) From air. Hucker (*loc. cit.*, 23) states that this species is probably identical with *Micrococcus candidus* Cohn or *Micrococcus epidermidis* Hucker.

Micrococcus populi Delacroix. (Bul. Mens. Off. Renseig. Agr., Paris, *5*, 1906, 1349 and Ann. Inst. Nat. Agron., 2 Ser., *5*, 1906, 353.) Parasitic on poplar trees (*Populus spp.*).

Micrococcus porcellorum Trevisan. (Micrococcus bei Hepatitis enzootica porcellorum, Nonewitsch, Cent. f. Bakt., *3*, 1888, 233; Trevisan, I generi e le specie delle Batteriacee, Milan, 1889, 33.) From an infected liver.

Micrococcus progrediens Schroeter. (Micrococcus der progressiven Abscessbildung bei Kaninchen, Koch, Über d. Aetiolog. d. Wundinfectionskrankheiten, Leipzig, 1878; Schroeter, in Cohn, Kryptogam.-Flora v. Schlesien, *3*, 1, 1886, 148; *Micrococcus haematosaprus* Trevisan, I generi e le specie delle Batteriacee, Milan, 1889, 33.) From the blood of diseased rabbits.

Micrococcus psalteri Buemann. (Cent. f. Bakt., I Abt., Orig., *71*, 1913, 308.) From the third stomach of cattle.

Micrococcus pseudocyaneus Schroeter. (Kryptogam.- Flora v. Schlesien, *3*, 1, 1886, 145.) A synonym of *Micrococcus cyaneus* Cohn according to Migula, Syst. d. Bakt., *2*, 1900, 188.

Micrococcus pseudoinfluenzae Migula. (Microörganismus I, Fischel, Ztschr. f. Heilkunde, *12*, 1891; See Cent. f. Bakt., *9*, 1891, 611; Migula, Syst. d. Bakt., *2*, 1900, 86.) From the blood of an influenza patient. Hucker (*loc. cit.*, 23) considers this a synonym of *Micrococcus candidus* Cohn or of *Micrococcus epidermidis* Hucker.

Micrococcus pulcher Glage. (Ztschr. f. Fleisch- u. Milchhyg., *10*, 1900, 146; not *Micrococcus pulcher* Weiss, Arb. bakt. Inst. Karlsruhe, *2*, Heft 3, 1902, 182.) From coating on surface of wurst and similar meat products.

Micrococcus pultiformis Kern. (Arb. bakt. Inst. Karlsruhe, *1*, Heft 4, 1897, 474.) From stomach contents of the yellow-hammer (*Emberiza citrinella*) and starling (*Sturnus vulgaris*) and from the intestine of the woodpecker (*Picus major*). Winslow and Winslow (*loc. cit.*, 199) state that this appears to be a synonym of *Micrococcus albus* Schroeter; while Hucker (*loc. cit.*, 19) regards it as probably identical with *Micrococcus freudenreichii* Guillebeau or with *Micrococcus ureae* Cohn.

Micrococcus punctatus Migula. (No. 18, Lembke, Arch. f. Hyg., *29*, 1897, 325; Migula, Syst. d. Bakt., *2*, 1900, 213.) From feces. Winslow and Winslow (*loc. cit.*, 199) state that this species appears to be a synonym of *Micrococcus albus* Schroeter.

Micrococcus purpurifaciens Lehmann and Neumann. (Micrococcus, Dudtschenko, Cent. f. Bakt., II Abt., *42*, 1915, 529; Lehmann and Neumann, Bakt. Diag., 6 Aufl., *2*, 1920, 755.) From ice. Produces a purple pigment in alkaline gelatin media.

Micrococcus pustulatus Henneberg. (Cent. f. Bakt., II Abt., *55*, 1922, 251.) From the human intestine.

Micrococcus putridus Tilanus. (Münch. med. Wchnschr., *34*, 1887, 310.) From gelatin, agar, etc., containing iodiform.

Micrococcus pygmaeus Henneberg (*loc. cit.*, 252). From the human intestine.

Micrococcus pyocyaneus Francisco. (Revista Valenciana de Ciencias Médicas, 1914, 2; Abst. in Cent. f. Bakt., I Abt., Ref., *63*, 1915, 44; not *Micrococcus pyocyaneus* Gessard, Thesis, Paris, 1882.) From an acne pustule.

Micrococcus pyosepticus (Héricourt and Richet) Solowjew. (*Staphylococcus pyosepticus* Héricourt and Richet, Compt.

rend. Acad. Sci., Paris, *107*, 1888, 691; Solowjew, Abst. in Cent. f. Bakt., I Abt., *18*, 1895, 60.) From an abscess in a dog and from dust. Regarded as identical with *Micrococcus albus* Schroeter.

Micrococcus quadrigeminus Klebs. (*Staphylococcus quadrigeminus* Vanselow and Czaplewski, Cent. f. Bakt., I Abt., *25*, 1899, 143; see Lehmann and Neumann, Bakt. Diag., 2 Aufl., *2*, 1899, 174.) Closely related to *Micrococcus albus* Schroeter.

Micrococcus quaternus Migula. (Siebert, Inaug. Diss., Würzburg, No. I, 1894, 7; Migula, Syst. d. Bakt., *2*, 1900, 92.) Winslow and Winslow (*loc. cit.*, 199) state that this appears to be a synonym of *Micrococcus albus* Schroeter.

Micrococcus radiatus Flügge. (Die Mikroorganismen, 2 Aufl., 1886, 176; *Streptococcus radiatus* Crookshank, Man. of Bact., 3rd ed., 1890, 256; not *Micrococcus radiatus* Kern, see below.) From dust and water. Winslow and Winslow (*loc. cit.*, 199) state that this appears to be a synonym of *Micrococcus albus* Schroeter; while Hucker (*loc. cit.*, 18) considers it a synonym of *Micrococcus caseolyticus* Evans.

Micrococcus radiatus Kern. (Kern, Arb. bakt. Inst. Karlsruhe, *1*, Heft 4, 1897, 471; *Micrococcus radiosus* Migula, Syst. d. Bakt., *2*, 1900, 114.) From the stomach contents of the starling (*Sturnus vulgaris*). Winslow and Winslow (*loc. cit.*, 199) state that this appears to be a synonym of *Micrococcus albus* Schroeter.

Micrococcus reessii Rosenthal. (Inaug. Diss., Berlin, 1893, 19; Abst. in Cent. f. Bakt., *16*, 1894, 1024.) From the oral cavity. Winslow and Winslow (*loc. cit.*, 199) state that this appears to be a synonym of *Micrococcus albus* Schroeter.

Micrococcus regularis Weiss. (Arb. bakt. Inst. Karlsruhe, *2*, Heft 3, 1902, 183.) From bean infusions. Hucker (*loc. cit.*, 7) considers this a synonym of *Micrococcus luteus* Cohn or *Micrococcus varians* Migula.

Micrococcus resinaceus Kern. (Arb. bakt. Inst. Karlsruhe, *1*, Heft 4, 1897, 487.) From the stomach contents of the starling (*Sturnus vulgaris*) and from the intestine of a sparrow (*Passer montanus*). Winslow and Winslow (*loc. cit.*, 220) regard this as a synonym of *Micrococcus luteus* Cohn.

Micrococcus rhenanus Migula. (Neuer Mikrococcus aus Rheinwasser, Burri, Arch. f. Hyg., *19*, 1893, 34; Migula, Syst. d. Bakt., *2*, 1900, 109; *Micrococcus rheni* Chester, Man. Determ. Bact., 1901, 82; *Albococcus rhenanus* Winslow and Rogers, Jour. Inf. Dis., *3*, 1906, 544.) From Rhine River water. Winslow and Winslow (*loc. cit.*, 199) state that this appears to be a synonym of *Micrococcus albus* Schroeter; while Hucker (*loc. cit.*, 18) considers it a synonym of *Micrococcus caseolyticus* Evans.

Micrococcus ridleyi Corbet. (Quart. Jour. Rubber Research Inst., Malaya, *2*, 1930, 146.) From the latex of the rubber tree (*Hevea brasiliensis*). For a description of this species, see Bergey et al., Manual, 5th ed., 1939, 244.

Micrococcus rosaceus Frankland and Frankland. (Trans. Roy. Society, London, *178*, B, 188, 269; *Rhodococcus rosaceus* Holland, Jour. Bact., *5*, 1920, 225.) From air. Hucker (*loc. cit.*, 25) states that this species may be identical with *Micrococcus roseus* Flügge. For a description of this species, see Bergey et al., Manual, 5th ed., 1939, 252.

Micrococcus rosaceus lactis Conn. (Storrs Agr. Exp. Sta. 12th Ann. Rept., 1900, 34; *Micrococcus lactis rosaceus* Conn, Esten and Stocking, Storrs Agr. Exp. Sta. Rept. for 1906, 108.) From milk.

Micrococcus roscidus Migula. (Micrococcus No. I, Adametz, Landwirtsch. Jahrb., *18*, 1889, 238; Migula, Syst. d. Bakt., *2*, 1900, 68.) From Emmenthal cheese. Winslow and Winslow (*loc. cit.*, 224) state that this is apparently a synonym of *Microccccus candicans* Flügge.

Micrococcus roseo-persicinus Migula.

(Rote Kokken von Van Ermengem, Schneider, Arb. bakt. Inst. Karlsruhe, *1*, Heft 2, 1894, 216; Migula, Syst. d. Bakt., *2*, 1900, 184.)

Micrococcus rosettaceus Zimmermann. (Bakt. unserer Trink- u. Nutzwässer, Chemnitz, I Reihe, 1890, 72.) From water. Winslow and Winslow (*loc. cit.*, 224) state that this is apparently a synonym of *Micrococcus candicans* Flügge.

Micrococcus roseus Maggiora. (Giorn. Soc. Ital. d'Igiene, *11*, 1889, 356; not *Micrococcus roseus* Flügge, Die Mikroorganismen, 2 Aufl., 1886, 183; not *Micrococcus roseus* Gruber, Cent. f. Bakt., II Abt., *22*, 1909, 408.)

Micrococcus rubellus Migula. (Syst. d. Bakt., *2*, 1900, 169.) Source not given. Hucker (*loc. cit.*, 27) regards this as identical with *Micrococcus cinnabareus* Flügge.

Micrococcus rubescens Migula. (No. 20, Lembke, Arch. f. Hyg., *26*, 1896, 312; Migula, Syst. d. Bakt., *2*, 1900, 208; not *Micrococcus rubescens* Chester, see *Micrococcus subroseus* below.) From feces. Hucker (*loc. cit.*, 27) regards this species as identical with *Micrococcus cinnabareus* Flügge.

Micrococcus rubidus lactis Conn. (Conn, Storrs Agr. Exp. Sta. 12th Ann. Rept., 1900, 34; *Micrococcus lactis rubidus* Conn, Esten and Stocking, Storrs Agr. Exp. Sta. 18th Ann. Rept., 1907, 117.) From milk. Resembles *Micrococcus cinnabareus* Flügge. Hucker (*loc. cit.*, 25) thinks this species may be identical with *Micrococcus roseus* Flügge.

Micrococcus rubigenosus Kern. (Arb. bakt. Inst. Karlsruhe, *1*, Heft 4, 1897, 492.) From the stomach contents of a dove (*Columba oenas*). Hucker (*loc. cit.*, 25) states that this species may be identical with *Micrococcus roseus* Flügge.

Micrococcus rubiginosus Passer. and Beltr. (Fung. Sicil., 18—, no. 35; quoted from DeToni and Trevisan, in Saccardo, Sylloge Fungorum, *8*, 1889, 1082.)

Micrococcus rugatus Migula. (*Micrococcus endocarditidis rugatus* Weichselbaum, Beitr. z. path. Anat. u. z. allgm. Pathol., *4*, 1889, 164; Migula, Syst. d. Bakt., *2*, 1900, 190; *Micrococcus endocarditis* Chester, Man. Determ. Bact., 1901, 74.) From ulcerative endocarditis. Winslow and Winslow (*loc. cit.*, 205) consider this a synonym of *Micrococcus candidus* Cohn or of *Gaffkya tetragena* Trevisan; while Hucker (*loc. cit.*, 15) regards it as a synonym of *Micrococcus albus* Schroeter.

Micrococcus rugosus Chester. (No. 2, Conn, Storrs Agr. Exp. Sta. 6th Ann. Rept., 1894, 50; Chester, Man. Determ. Bact., 1901, 101.) From milk and ripened cream. Winslow and Winslow (*loc. cit.*, 216) consider this a synonym of *Micrococcus flavus* Trevisan.

Micrococcus ruminantium Henneberg. (Cent. f. Bakt., II Abt., *55*, 1922, 252.) From the human intestine.

Micrococcus rushmorei Brown. (Amer. Museum Novit., No. 251, 1927, 4.) Isolated from a fly (*Lucilia sericata*) which was infected with *Bacillus lutzae*.

Micrococcus saccatus Migula. (*Micrococcus albus liquefaciens* von Besser, Beitr. z. path. Anat., *6*, 1889, 46; *Micrococcus liquefaciens albus*, see Cent. f. Bakt., *7*, 1890, 152; Migula, Syst. d. Bakt., *2*, 1900, 117; *Micrococcus liquefaciens* Chester, Man. Determ. Bact., 1901, 78; not *Micrococcus liquefaciens* Holland, Jour. Bact., *5*, 1920, 224; *Micrococcus alvi* Chester, *loc. cit.*, 81.) From the nasal mucous membrane. Winslow and Winslow (*loc. cit.*, 199) state that this is apparently a synonym of *Micrococcus albus* Schroeter; while Hucker (*loc. cit.*, 19) regards it as probably identical with *Micrococcus freudenreichii* Guillebeau or with *Micrococcus ureae* Cohn. For a description of this species, see Bergey et al., Manual, 5th ed., 1939, 254.

Micrococcus salivalis septicus, quoted from Wigura, see Cent. f. Bakt., I Abt., *17*, 1895, 899. From the human skin.

Micrococcus sarcinoides Migula. (Syst. d. Bakt., *2*, 1900, 168.) Hucker

(*loc. cit.*, 27) considers this identical with *Micrococcus cinnabareus* Flügge.

Micrococcus scariosus Migula. (Siebert, Inaug. Diss., Würzburg, No. II, 1894, 9; Migula, Syst. d. Bakt., *2*, 1900, 91.) From a hairbrush. Winslow and Winslow (*loc. cit.*, 199) state that this appears to be a synonym of *Micrococcus albus* Schroeter.

Micrococcus scarlatinosus Trevisan. (Trevisan, Batteri italiani, 1879, 19; *Streptococcus rubiginosus* Edington, Brit. Med. Jour., *1*, 1887, 1265; *Perroncitoa scarlatinosa* Trevisan, I generi e le specie delle Batteriacee, Milan, 1889, 29.) From a scarlet fever patient.

Micrococcus scarlatinus Migula. (Syst. d. Bakt., *2*, 1900, 173.) From feces.

Micrococcus selenicus Brenner. (Jahrb. f. wissensch. Botan., *57*, 1916, 85; Abst. in Cent. f. Bakt., II Abt., *48*, 1918, 431.) From mud.

Micrococcus sensibilis Zettnow. (Cent. f. Bakt., I Abt., Orig., *77*, 1915, 216.) From dust. Hucker (*loc. cit.*, 19) considers this a synonym of *Micrococcus freudenreichii* Guillebeau or of *Micrococcus ureae* Cohn. For a description of this species, see Bergey et al., Manual, 5th ed., 1939, 248.

Micrococcus septicus (Klebs) Cohn. (*Microsporon septicum* Klebs, Die Ursachen der infectiösen Wundkrankheiten, 1871; and Zur path. Anat. d. Schusswunden, 1872; Cohn, Beitr. z. Biol. d. Pflanzen, *1*, Heft 2, 1872, 164.) From pus.

Micrococcus serophilus Costa. (Compt. rend. Soc. Biol., Paris, *83*, 1920, 931.) From acute articular rheumatism.

Micrococcus serratus Migula. (No. 15, Lembke, Arch. f. Hyg., *26*, 1896, 309; Migula, Syst. d. Bakt., *2*, 1900, 200.) From feces. Winslow and Winslow (*loc. cit.*, 205) regard this as a synonym of *Micrococcus candidus* Cohn or of *Gaffkya tetragena* Trevisan.

Micrococcus sialosepticus Trevisan. (*Coccus salivarius septicus* Biondi, Ztschr. f. Hyg., *2*, 1887, 195; *Coccus septicus* Biondi, *ibid.*, 220; Trevisan, I generi e le specie delle Batteriacee, Milan, 1889, 33; *Micrococcus salivarius* Migula, Syst. d. Bakt., *2*, 1900, 65; *Micrococcus salivarius-septicus* Chester, Man. Determ. Bact., 1901, 87.) From human saliva. Winslow and Winslow (*loc. cit.*, 205) consider this a synonym of *Micrococcus candidus* Cohn or of *Gaffkya tetragena* Trevisan.

Micrococcus siccus Migula. (Micrococcus No. V, Adametz, Landwirtsch. Jahrb., *18*, 1889, 241; Migula, Syst. d. Bakt., *2*, 1900, 124.) From Emmenthal cheese. Winslow and Winslow (*loc. cit.*, 185) state that this is probably a synonym of *Micrococcus aurantiacus* Cohn; while Hucker (*loc. cit.*, 7) considers it a synonym of *Micrococcus luteus* Cohn or of *Micrococcus varians* Migula.

Micrococcus similis Dyar. (Ann. N. Y. Acad. Sci., *8*, 1895, 347.) From dust. Winslow and Winslow (*loc. cit.*, 205) regard this as a synonym of *Micrococcus candidus* Cohn or of *Gaffkya tetragena* Trevisan.

Micrococcus simplex Wright. (Mem. Nat. Acad. Sci., *7*, 1895, 432.) From Schuylkill River water. Winslow and Winslow (*loc. cit.*, 199) state that this appears to be a synonym of *Micrococcus albus* Schroeter.

Micrococcus simulans DeToni and Trevisan. (*Micrococcus citreus II*, Maggiora, Giorn. Soc. Ital. d'Igiene, *11*, 1889, 354; DeToni and Trevisan, in Saccardo, Sylloge Fungorum, *8*, 1889, 1079.)

Micrococcus sordidus Schroeter. (Schroeter in Cohn, Kryptogam.-Flora v. Schlesien, *3*, 1, 1886, 145.) Winslow and Winslow (*loc. cit.*, 224) state that this is apparently a synonym of *Micrococcus candicans* Flügge.

Micrococcus sphaeroides Gray and Thornton. (Cent. f. Bakt., II Abt., *73*, 1928, 74.) From manure and soil. For a description of this species, see Bergey et al., Manual, 5th ed., 1939, 259.

Micrococcus staphylophagus Serbinov.

(La Defense des Plantes, Leningrad, *2*, 1926, 556; see Rev. Appl. Mycol., *5*, 1926, 650.) Considered pathogenic on grapevines.

Micrococcus stellatus (Lustig) Frankland and Frankland. (Stern-Coccus, Maschek, Jahresber. d. Kom.- Oberrealschule, Leitmeritz, No. 10, 1887, 62; *Coccus stellatus* Lustig, Diag. d. Bakt. d. Wassers, 2 Aufl., 1893, 40; Frankland and Frankland, Micro-organisms in Water, 1894, 503.) From water. Winsolw and Winslow (*loc. cit.*, 220) regard this as a synonym of *Micrococcus luteus* Cohn.

Micrococcus strobiliformis Migula. (No. 23, Lembke, Arch. f. Hyg., *26*, 1896, 315; Migula, Syst. d. Bakt., *2*, 1900, 203.) From feces. Winslow and Winslow (*loc. cit.*, 220) regard this as a synonym of *Micrococcus luteus* Cohn.

Micrococcus subcandicans Lavanchy. (Univ. Genève, Inst. bot. Prof. Chodat, Sér. 8, Fasc. 12, 1914, 68; Abst. in Cent. f. Bakt., II Abt., *47*, 1917, 611.) From water of Lake Geneva.

Micrococcus subcanus Migula. (No. 17, Lembke, Arch. f. Hyg., *26*, 1896, 311; Migula, Syst. d. Bakt., *2*, 1900, 202.) From feces. Winslow and Winslow (*loc. cit.*, 224) state that this is apparently a synonym of *Micrococcus candicans* Flügge.

Micrococcus subcarneus Migula. (*Micrococcus carnicolor* Kern, Arb. bakt. Inst. Karlsruhe, *1*, Heft 4, 1897, 495; not *Micrococcus carnicolor* Frankland and Frankland, Micro-organisms in water, 1894, 503; Migula, Syst. d. Bakt., *2*, 1900, 181.) From the intestines of doves (*Columba livia* and *Columba oenas*). Hucker (*loc. cit.*, 26) states that this may be identical with *Micrococcus roseus* Flügge.

Micrococcus subcitreus Migula. (Citronengelber Micrococcus, Keck, Ueber das Verhalten der Bakterien im Grundwasser, Dorpat Dissertation, 1890, 60; Migula, Syst. d. Bakt., *2*, 1900, 147.) From air and water. Winslow and Winslow (*loc. cit.*, 216) consider this a synonym of *Micrococcus flavus* Trevisan. For a description of this species, see Bergey et al., Manual, 5th ed., 1939, 249.

Micrococcus subcretaceus Migula. (Kreideweisserverflüssigender *Micrococcus*, Keck, Inaug. Diss., Dorpat, 1890, 64; Migula, Syst. d. Bakt., *2*, 1900, 107.) Winslow and Winslow (*loc. cit.*, 199) state that this species appears to be a synonym of *Micrococcus albus* Schroeter.

Micrococcus subflavescens Bergey et al. (Manual, 1st ed., 1923, 61.) From dust and water. Hucker (*loc. cit.*, 9) considers this a synonym of *Micrococcus flavus* Trevisan. For a description of this species, see Bergey et al., Manual, 5th ed., 1939, 246.

Micrococcus subflavidus Migula. (*Micrococcus tetragenus subflavus* v. Besser, Beitr. z. allgm. Path. u. path. Anat., *6*, 1889, 347; Migula, Syst. d. Bakt., *2*, 1900, 190; *Micrococcus subflavus* Chester, Man. Determ. Bact., 1901, 96; not *Micrococcus subflavus* Flügge, Die Mikroorganismen, 2 Aufl., 1886, 159.) From normal nasal mucus. Winslow and Winslow (*loc. cit.*, 184) state that this is apparently a synonym of *Micrococcus aureus* Zopf; while Hucker (*loc. cit.*, 7 and 21) considers it probably identical with *Micrococcus luteus* Cohn, *Micrococcus varians* Migula, or *Gaffkya tetragena* Trevisan.

Micrococcus subflavus Flügge. (Gelbweisser Diplococcus, Bumm, Die Mikroorg. d. gonorrh. Schleimhauterkr., 1 Aufl., 1885 and 2 Aufl., 1887, 20; Flügge, Die Mikroorganismen, 2 Aufl., 1886, 159; *Neisseria subflava* Trevisan, I generi e le specie delle Batteriacee, Milan, 1889, 32; *Diplococcus subflavus* Eisenberg, Bakt. Diag., 3 Aufl., 1891, 307; not *Micrococcus subflavus* Chester, Man. Determ. Bact., 1901, 96.) From gonorrheal pus. Winslow and Winslow (*loc. cit.*, 216) consider this a synonym of *Micrococcus flavus* Trevisan. For a description of this species, see Bergey et al., Manual, 5th ed., 1939, 248.

Micrococcus subfuscus Matzuschita (Cent. f. Bakt., I Abt., *29*, 1901, 383.)

From dust. Similar to *Micrococcus fuscus* Adametz.

Micrococcus subgilvus Migula. (*Micrococcus gilvus* Henrici, Arb. a bakt. Inst. Karlsruhe, *1*, Heft 1, 1894, 78; not *Micrococcus gilvus* Losski, Inaug. Diss., Dorpat, 1893, 60; Migula, Syst. d. Bakt., *2*, 1900, 132.) From cheese. Winslow and Winslow (*loc. cit.*, 220) regard this as a synonym of *Micrococcus luteus* Cohn.

Micrococcus subgranulatus Migula. (*Micrococcus citreus granulatus* Freund, Inaug. Diss., Erlangen, 1893, 27; Migula, Syst. d. Bakt., *2*, 1900, 148; *Micrococcus granulatus* v. Bagarewski, Cent. f. Bakt., II Abt., *15*, 1905, 7.) From the oral cavity. Winslow and Winslow (*loc. cit.*, 216) consider this a synonym of *Micrococcus flavus* Trevisan. For a description of this species, see Bergey et al., Manual, 5th ed., 1939, 249.

Micrococcus subgriseus Migula. (Grauer Coccus, Maschek, Jahresb. d. Kom.- Oberrealschule, Leitmeritz, No. 8, 1887, 61; Migula, Syst. d. Bakt., *2*, 1900, 94.) From water. Winslow and Winslow (*loc. cit.*, 199) state that this appears to be a synonym of *Micrococcus albus* Schroeter; while Hucker (*loc. cit.*, 19) regards it as a synonym of *Micrococcus freudenreichii* Guillebeau or of *Micrococcus ureae* Cohn.

Micrococcus sublacteus Migula. (No. 27, Lembke, Arch. f. Hyg., *29*, 1897, 329; Migula, Syst. d. Bakt., *2*, 1900, 210.) From feces. Winslow and Winslow (*loc. cit.*, 199) state that this appears to be a synonym of *Micrococcus albus* Schroeter; while Hucker (*loc. cit.*, 19) regards it as a synonym of *Micrococcus freudenreichii* Guillebeau or of *Micrococcus ureae* Cohn.

Micrococcus sublilacinus Migula. (No. 26, Lembke, Arch. f. Hyg., *26*, 1896, 317; Migula, Syst. d. Bakt., *2*, 1900, 205.) From feces. Hucker (*loc. cit.*, 15) considers this a synonym of *Micrococcus albus* Schroeter.

Micrococcus subluteus Weiss. (Arb. bakt. Inst. Karlsruhe, *2*, Heft 3, 1902, 198.) From vegetable infusions.

Micrococcus subniveus Migula. (*Micrococcus albidus* Henrici, Arb. bakt. Inst. Karlsruhe, *1*, Heft 1, 1894, 75; not *Micrococcus albidus* Losski, Inaug. Diss., Dorpat, 1893, 55; Migula, Syst. d. Bakt., *2*, 1900, 105.) From Swiss cheese. Winslow and Winslow (*loc. cit.*, 199) state that this appears to be a synonym of *Micrococcus albus* Schroeter.

Micrococcus subochraceus Migula. (No. 30, Lembke, Arch. f. Hyg., *29*, 1897, 332; Migula, Syst. d. Bakt., *2*, 1900, 215.) From feces. Winslow and Winslow (*loc. cit.*, 216) regard this as a synonym of *Micrococcus flavus* Trevisan.

Micrococcus subroseus Migula. (*Micrococcus roseus* Eisenberg, Bakt. Diag., 3 Aufl., 1891, 408; Migula, Syst. d. Bakt., *2*, 1900, 176; *Micrococcus rubescens* Chester, Man. Determ. Bact., 1901, 105.) From the sputum of an influenza patient. Hucker (*loc. cit.*, 26) states that this may be identical with *Micrococcus roseus* Flügge.

Micrococcus subterraneus Hansgirg. (Hansgirg, Oest. Bot. Zeitschr., 1888, No. 7–8, 8; *Staphylococcus subterraneus* DeToni and Trevisan in Saccardo, Sylloge Fungorum, *8*, 1889, 1075.) From damp walls of wine cellars in Bohemia.

Micrococcus subtilis Migula. (Diplococcus, Kirchner, Ztschr. f. Hyg., *9*, 1890, 528; Migula, Syst. d. Bakt., *2*, 1900, 192.) Found in the sputum and blood of influenza patients.

Micrococcus succulentus Henrici. (Arb. bakt. Inst. Karlsruhe, *1*, Heft 1, 1894, 63.) From Swiss cheese. Winslow and Winslow (*loc. cit.*, 224) state that this is apparently a synonym of *Micrococcus candicans* Flügge.

Micrococcus sulphureus Zimmermann. (Bakt. unserer Trink- u. Nutzwässer, Chemnitz, I Reihe, 1890, 84.) From water. Winslow and Winslow (*loc. cit.*, 220) regard this as a synonym of *Micrococcus luteus* Cohn.

Micrococcus suis Burrill. (*Bacillus*

suis Detmers, Rept. U. S. Dept. Agric. for 1878; Burrill, Amer. Nat., *17*, 1883, 320.) From blood of hogs sick with swine plague or hog cholera.

Micrococcus syphiliticus Migula. (Coccen, Disse, Deutsche med. Wchnschr., *13*, 1887, 888; Migula, Syst. d. Bakt., *2*, 1900, 218.) This may be synonymous with *Micrococcus candicans* Flügge.

Micrococcus tardigradus Trevisan. (*Micrococcus flavus tardigradus* Flügge, Die Mikroorganismen, 2 Aufl., 1886, 175; Trevisan, I generi e le specie delle Batteriacee, Milan, 1889, 34; *Micrococcus sulfureus β-tardigradus* Lehmann and Neumann, Bakt. Diag., 1 Aufl., *2*, 1896, 163; *Micrococcus sulfureus* var. *tardigradus* Löhnis and Pillai, Cent. f. Bakt., II Abt., *19*, 1907, 92.) From air; also found in water. Winslow and Winslow (*loc. cit.*, 220) regard this as a synonym of *Micrococcus luteus* Cohn.

Micrococcus tardior Migula. (*Diplococcus flavus liquefaciens tardus* Unna and Tommasoli, Monatshefte f. prakt. Dermatol., *9*, 1889, 56; Migula, Syst. d. Bakt., *2*, 1900, V and 141; *Micrococcus epidermis* Chester, Man. Determ. Bact., 1901, 97; *Diplococcus flavus-liquefaciens* Chester, *ibid.*) From eczema. Winslow and Winslow (*loc. cit.*, 216) regard this as a synonym of *Micrococcus flavus* Trevisan; while Hucker (*loc. cit.*, 11) regards it as a synonym of *Micrococcus citreus* Migula.

Micrococcus tardissimus (Trevisan) Migula. (Milchweisser Micrococcus, Bumm, Mikroorg. d. gonorrh. Schleimhauterkr., 1 Aufl., 1885; *Diplococcus albicans tardissimus* Flügge, Die Mikroorganismen, 2 Aufl., 1886, 183; *Neisseria tardissima* Trevisan, I generi e le specie delle Batteriacee, Milan, 1889, 32; *Micrococcus albicans tardissimus* Sternberg, Man. of Bact., 1893, 882; Migula, Syst. d. Bakt., *2*, 1900, 49.) Found in vaginal secretions. Winslow and Winslow (*loc. cit.*, 205) regard this as a synonym of *Micrococcus candidus* Cohn or of *Gaffkya tetragena* Trevisan; while Hucker (*loc. cit.*, 7) considers it a synonym of *Micrococcus luteus* Cohn or *Micrococcus varians* Migula.

Micrococcus tardus Migula. (*Diplococcus albicans tardus* Unna and Tommasoli, Monatshefte f. prakt. Dermatol., *9*, No. 2, 1889, 49; *Micrococcus albicans tardus* Sternberg, Man. of Bact., 1893, 882; Migula, Syst. d. Bakt., *2*, 1900, 50; *Micrococcus eczemae* Chester, Man. Determ. Bact., 1901, 86). From eczema. Winslow and Winslow (*loc. cit.*, 216 and 224) regard this as a synonym of *Micrococcus flavus* Trevisan or of *Micrococcus candicans* Flügge.

Micrococcus tenacatis Chester. (No. 43, Conn, Storrs Agr. Exp. Sta. 7th Ann. Rept., 1895, 78; Chester, Man. Determ. Bact., 1901, 88.) From milk from Uruguay. Winslow and Winslow (*loc. cit.*, 220) state that this is apparently a synonym of *Micrococcus candicans* Flügge.

Micrococcus tener Weiss. (Arb. bakt. Inst. Karlsruhe, *2*, Heft 3, 1902, 200.) From a vegetable infusion.

Micrococcus tenuissimus Migula. (*Micrococcus cumulatus tenuis* v. Besser, Beitr. z. path. Anat., *6*, 1889, 347; Migula, Syst. d. Bakt., *2*, 1900, 55; *Micrococcus cumulatus* Chester, Man. Determ. Bact., 1901, 87.) Frequently found in human nasal mucus. Winslow and Winslow (*loc. cit.*, 205) regard this as a synonym of *Micrococcus candidus* Cohn or of *Gaffkya tetragena* Trevisan.

Micrococcus tetragenus aureus Boutron. (Thèse, Paris, 1893; Abst. in Cent. f. Bakt., *16*, 1894, 971.) Hucker (*loc. cit.*, 21) regards this as a synonym of *Gaffkya tetragena* Trevisan.

Micrococcus tetragenus concentricus Schenk. (Allg. Wien. med. Zeitung, 1892, 81 and 92; Abst. in Cent. f. Bakt., *13*, 1893, 720.) From feces. Motile.

Micrococcus tetragenus-pallidus Chester. (*Micrococcus tetragenus pallidus*, Dyar, Ann. N. Y. Acad. Sci., *8*, 1895, 354; Chester, Man. Determ. Bact., 1901, 93.) From dust. Probably a variety of *Micrococcus versatilis* Chester, see below.

Micrococcus tetragenus-vividus Chester. (*Micrococcus tetragenus vividus* Dyar, Ann. N. Y. Acad. Sci., *8*, 1895, 354; Chester, Man. Determ. Bact., 1901, 102.) From dust. Probably a variety of *Micrococcus versatilis* Chester, see below.

Micrococcus tetras Henrici. (Arb. bakt. Inst. Karlsruhe, *1*, Heft 1, 1894, 60; *Pediococcus tetras* Pribram, Klassifikation der Schizomyceten, 1933, 46.) From cheese. Winslow and Winslow (*loc. cit.*, 224) state that this species is apparently the same as *Micrococcus candicans* Flügge.

Micrococcus thermophilus Hansgirg. (Oestr. Bot. Ztschr., No. 3, 1888, 5.) From hot springs.

Micrococcus toxicatus Burrill. (Amer. Nat., *17*, 1883, 319.) From poison ivy and other plants in the genus *Rhus*.

Micrococcus trachomatis Migula. (Trachomococcus, Sattler, in Zehender, Klin. Monatsbl., 1881; Trachomococcus, Michel, Arch. f. Augenheilk., *16*, 1886; *Neisseria micheli* Trevisan, I generi e le specie delle Batteriacee, Milan, 1889, 32; see Baumgarten, Lehrb. d. path. Mykol., *1*, 1890, 421; Migula, Syst. d. Bakt., *2*, 1900, 67.) Winslow and Winslow (*loc. cit.*, 205) consider this to be a synonym of *Micrococcus candidus* Cohn or of *Gaffkya tetragena* Trevisan.

Micrococcus tributyrus Stark and Scheib. (Jour. Dairy Sci., *19*, 1936, 210.) From butter.

Micrococcus tritici Prillieux. (Maladies des plantes agricoles, *1*, 1895, 7; not *Micrococcus tritici* Köck, Monatshefte f. Landwirtschaft, 1909, 247, quoted from Lehmann and Neumann, Bakt. Diag., 5 Aufl., *2*, 1912, 653.) Considered pathogenic on wheat.

Micrococcus tuberculosus Migula. (No. 23, Lembke, Arch. f. Hyg., *29*, 1897, 325; Migula, Syst. d. Bakt., *2*, 1900, 214.) From feces. Winslow and Winslow (*loc. cit.*, 224) state that this is apparently a synonym of *Micrococcus candicans* Flügge.

Micrococcus typhoideus Migula. (Coccus A, Foutin, Bakt. Untersuch. v. Hagel, Wratsch, 1889, No. 49 and 50; see Cent. f. Bakt., *7*, 1890, 373; Migula, Syst. d. Bakt., *2* 1900, 94; *Micrococcus alpha* Chester, Man. Determ. Bact., 1901, 93.) From hail. Winslow and Winslow (*loc. cit.*, 199) state that this appears to be a synonym of *Micrococcus albus* Schroeter; while Hucker (*loc. cit.*, 25) states that it may be identical with *Micrococcus roseus* Flügge.

Micrococcus ulceris de Luca. (Gazzetta degli Ospitali, 1886; Abst. in Cent. f. Bakt., *1*, 1887, 333; *Micrococcus ulceris mollis* de Luca, *ibid.*) From the secretion of a venereal ulcer.

Micrococcus ulmi Brussoff. (Cent. f. Bakt., II Abt., *63*, 1925, 261.) Isolated from diseased elm trees.

Micrococcus umbilicatus Weiss. (Arb. bakt. Inst. Karlsruhe, *2*, Heft 3, 1902, 186.) From a bean infusion. Hucker (*loc. cit.*, 12) considers this a synonym of *Micrococcus aureus* Zopf.

Micrococcus ureae Migula. (Torule ammoniacale, Pasteur, Ann. de Chim. et de Phys., 3 sér., *64*, 1862, 52; van Tieghem, Comp. rend. Acad. Sci., Paris, *58*, 1864, 210; *Torula ureae* Lea, Jour. of Physiol., *11*, 1890, 226; Migula, in Engler and Prantl, Die natürl. Pflanzenfam., *1*, 1a, 1895, 17.) From urine. May not be the same as *Micrococcus ureae* Cohn.

Micrococcus urinalbus De Toni and Trevisan. (*Micrococcus albus urinae* Doyen, Jour. d. connaiss. médic., No. 14, 1889, 108; De Toni and Trevisan, in Saccardo, Sylloge Fungorum, *8*, 1889, 1076.) From urine. Hucker (*loc. cit.*, 15) considers this a synonym of *Micrococcus albus* Schroeter.

Micrococcus uruguae Chester. (No. 40, Conn, Storrs Agr. Exp. Sta. 7th Ann. Rept., 1895, 78; Chester, Man. Determ. Bact., 1901, 100.) From milk from Uruguay. Winslow and Winslow (*loc. cit.*, 216) regard this as a synonym of

Micrococcus flavus Trevisan; while Hucker (*loc. cit.*, 10) regards it as a synonym of *Micrococcus conglomeratus* Migula.

Micrococcus utriculosus Migula. (No. 20, Lembke, Arch. f. Hyg., *29*, 1897, 327; Migula, Syst. d. Bakt., *2*, 1900, 199.) From feces. Winslow and Winslow (*loc. cit.*, 199) state that this appears to be a synonym of *Micrococcus albus* Schroeter.

Micrococcus varians lactis Conn. (Storrs Agr. Exp. Sta. 12th Ann. Rept., 1900, 37.) From milk, cream, dust. According to Weigmann (In Lafar, Handb. d. techn. Mykologie, *2*, 1905, 13) this is identical with *Staphylococcus mastitis albus*. Hucker (*loc. cit.*, 11) regards it as a synonym of *Micrococcus citreus* Migula.

Micrococcus variococcus Müller-Thurgau and Osterwalder. (Cent. f. Bakt., II Abt., *36*, 1913, 236.) From wine.

Micrococcus versatilis Chester. (*Micrococcus tetragenus febris flavae* Finlay; *Micrococcus tetragenus versatilis* Sternberg, Report on etiology and prevention of yellow fever, Washington, 1891, 164; Chester, Man. Determ. Bact., 1901, 102.) Isolated from the excrement of mosquitoes which had sucked the blood of yellow fever patients; and from dust. Winslow and Winslow (*loc. cit.*, 216) regard this as a synonym of *Micrococcus flavus* Trevisan.

Micrococcus versicolor Flügge. (Die Mikroorganismen, 2 Aufl., 1886, 177.) From dust. Winslow and Winslow (*loc. cit.*, 220) consider this a synonym of *Micrococcus luteus* Cohn.

Micrococcus vesicae Heim. (Lehrb. d. Bakt., 2 Aufl., 1898, 297.) From acid urine. Winslow and Winslow (*loc. cit.*, 224) state that this is apparently a synonym of *Micrococcus candicans* Flügge.

Micrococcus vesicans Harman. (Jour. Path. and Bact., *9*, 1904, 1.) Considered the cause of veld sore, a disease of Africa and tropical Australia.

Micrococcus vesicosus Weiss. (Arb. bakt. Inst. Karlsruhe, *2*, Heft 3, 1902, 203.) From a vegetable infusion. Hucker (*loc. cit.*, 8) considers this species identical with either *Micrococcus luteus* Cohn or *Micrococcus varians* Migula.

Micrococcus vesiculiferus Migula. (No. 28, Lembke, Arch. f. Hyg., *29*, 1897, 330; Migula, Syst. d. Bakt., *2*, 1900, 211.) From feces. Winslow and Winslow (*loc. cit.*, 220) regard this as a synonym of *Micrococcus luteus* Cohn.

Micrococcus vincenzii Chester. (*Micrococcus tetragenus citreus* Vincenzi, La Riforma Med., 1897, 758; Chester, Man. Determ. Bact., 1901, 103.) From the submaxillary lymphatic gland of a child. Winslow and Winslow (*loc. cit.*, 220) regard this as a synonym of *Micrococcus luteus* Cohn.

Micrococcus vini Migula. (*Micrococcus saprogenes vini I*, Kramer, Bakt. in Beziehungen z. Landwirtsch. u. d. landwirtsch-techn. Gewerben, II Teil, 1892, 139; Migula, Syst. d. Bakt., *2*, 1900, 118.) From wine. Winslow and Winslow (*loc. cit.*, 199) state that this appears to be a synonym of *Micrococcus albus* Schroeter; while Hucker (*loc. cit.*, 8) considers it identical with *Micrococcus luteus* Cohn or *Micrococcus varians* Migula.

Micrococcus viniperda Schroeter. (Schroeter in Cohn, Kryptog.-Flora v. Schlesien, *3*, 1, 1886, 144.) From dust, feces, etc.

Micrococcus viscosus Bergey et al. (*Micrococcus lactis viscosus B*, Conn, Esten and Stocking, Storrs Agr. Exp. Sta. Rept. for 1906, 109; Bergey et al., Manual, 1st ed., 1923, 68.) From pasteurized milk. For a description of this species, see Bergey et al., Manual, 5th ed., 1939, 256. See *Micrococcus lactis viscosus* Sternberg.

Micrococcus viscosus lactis Conn. (Storrs Agr. Exp. Sta. 12th Ann. Rept., 1900, 44.) From milk.

Micrococcus viticulosus Flügge. (Die Mikroorganismen, 2 Aufl., 1886, 178.) From dust and water. Winslow and Winslow (*loc. cit.*, 205) consider this to

be a synonym of *Micrococcus candidus* Cohn or of *Gaffkya tetragena* Trevisan.

Micrococcus vulgaris Eckstein. (Ztschr. f. Forst- u. Jagdwesen, *26*, 1894, 17; Abst. in Cent. f. Bakt., I Abt., *18*, 1895, 292; not *Micrococcus vulgaris* Weiss, Arb. bakt. Inst. Karlsruhe, *2*, Heft 3, 1902, 193.) From insects.

Micrococcus xanthogenicus (Freire) Trevisan. (*Cryptococcus xanthogenicus* Freire, Recherches sur la cause de la fièvre jaune, Rio de Janeiro, 1884; Trevisan, I generi e le specie delle Batteriacee, Milan, 1889, 33.) Isolated from yellow fever and supposed by Freire to be the cause of the disease. Winslow and Winslow (*loc. cit.*, 199) state that this appears to be a synonym of *Micrococcus albus* Schroeter.

Micrococcus xenopus Schrire and Greenfield. (Trans. Royal Soc. So. Africa, *17*, 1930, 309.) From an abscess in a toad (*Xenopus sp.*). For a description of this species, see Bergey et al., Manual, 5th ed., 1939, 243.

Micrococcus xerophilus Glage. (Ztschr. f. Fleisch- u. Milchhygiene, *10*, 1900, 145.) From coating on surface of dry wurst and similar meat products.

Micrococcus zeae Serbinov. (La Defense des Plantes, *2*, 1926, 546.) From flour, grain and seedlings of corn. Was thought to be a cause of pellagra in South Russia.

Micrococcus zonatus Henrici. (Arb. bakt. Inst. Karlsruhe, *1*, Heft 1, 1894, 68.) From cheese. Winslow and Winslow (loc. cit., 224) state that this is apparently a synonym of *Micrococcus candicans* Flügge.

Planococcus casei Migula. (Micrococcus No. III, Adametz, Landwirtsch. Jahrb., *18*, 1889, 240; Migula, Syst. d. Bakt., *2*, 1900, 270.) From Emmenthal cheese.

Planococcus loeffleri Migula. (Löffler, Cent. f. Bakt., *7*, 1890, 637; Migula, Syst. d. Bakt., *2*, 1900, 273.) From colony on an old gelatin plate.

Planococcus luteus (Adametz) Migula. (*Diplococcus luteus* Adametz, Mitteil. d. oesterr. Vers. Station f. Brauerei u. Mälzerei in Wien, Heft I, 1888, 39; *Neisseria lutea* Trevisan, I generi e le specie delle Batteriacee, Milan, 1889, 32; Migula, Syst. d. Bakt., *2*, 1900, 274.) Hucker (*loc. cit.*, 9) considers this species a synonym of *Micrococcus flavus* Trevisan.

Rhodococcus fulvus Winslow and Rogers. (Jour. Inf. Dis., *8*, 1906, 545; not *Micrococcus fulvus* Cohn, Beitr. z. Biol. d. Pflanzen, *1*, Heft 3, 1875, 181.) From soil, air and water.

Staphylococcus albicans Stigell. (Cent. f. Bakt., I Abt., Orig., *45*, 1908, 489.) Probably intended for *Micrococcus albicans amplus* Flügge.

Staphylococcus albus liquefaciens Sternberg. (White liquefying staphylococcus, Escherich, Die Darmbakterien des Säuglings, Stuttgart, 1886, 88; Sternberg, Manual of Bact., 1893, 607.) Found occasionally in the feces of healthy infants.

Staphylococcus albus non liquefaciens Hlava. (Sborník lékařský, II, Prague, 1887, 12 pp.; see Cent. f. Bakt., *2*, 1887, 688.) Probably a synonym of *Micrococcus albocereus* Migula.

Staphylococcus anaerobius Heurlin. (Bakt. Unters. d. Keimgehaltes im Genitalkanale d. fiebernden Wöchnerinnen, Helsingfors, 1910, 120.) See Weinberg, Nativelle and Prévot, Les Microbes Anaérobies, Paris, 1937, 1027; probably not the same as *Staphylococcus anaerobius* Hamm, Die puerperale Wundinfektion, Berlin, 1912. Incompletely described. From genital tract.

Staphylococcus anaerobius major Heurlin (*loc. cit.*, 120). From genital tract.

Staphylococcus anaerobius minor Heurlin (*loc. cit.*, 120). From genital tract.

Staphylococcus aureus sarciniformis Rosenhauch. (Klin. Monatsbl. f. Augenheilkunde, Jahrg., *8*, 1909, 257; Abst. in Cent. f. Bakt., I Abt., Ref., *45*, 1910, 787.)

Staphylococcus bovis Ford. (*Staphylococcus pyogenes bovis* Lucet, Ann. Inst.

Past., 7, 1893, 327; Ford, Textb. of Bact., 1927, 424.) Found in suppurative lesions of cattle.

Staphylococcus candidus Warrington. (Lancet, *1*, 1888.)

Staphylococcus flavocyaneus Knaysi. (Jour. Bact., *43*, 1942, 368.) Found as a contaminant in dissociation studies.

Staphylococcus flavus non pyogenes Fränkel and Sänger. (Arch. f. path. Anat., *108*, 1887, 286; Abst. in Cent. f. Bakt., *3*, 1888, 281.) Found in endocarditis ulcerosa.

Staphylococcus griseus Tavel. (Quoted from Lehmann and Neumann, Bakt. Diag., 1 Aufl., *2*, 1896, 173.) From pus.

Staphylococcus griseus radiatus Viti. (Atti d. R. Accad. d. Fisiocritici di Siena, Ser. IV., 2, 1891, Abst. in Cent. f. Bakt., *11*, 1892, 672.) From cases of endocarditis.

Staphylococcus habanensis Gibler. (Quoted from Fernandez, Cronica médico quirúrgica de la Habana, 1891, No. 30; Abst. in Cent. f. Bakt., *11*, 1892, 472.) Isolated from the human eye.

Staphylococcus insectorum Krassilstschik. (Quoted from Paillot, Les maladies du ver à soie grasserie et dysenteries, 1928, 171.) From the intestinal tract of the silkworm (*Bombyx mori*).

Staphylococcus lactis acidi McDonnell. (Inaug. Diss., Kiel, 1899; Abst. in Cent. f. Bakt., II Abt., *6*, 1900, 120.)

Staphylococcus leloirii Trevisan. (Microbe des périfolliculites conglomérées, Leloir, Soc. anatomique, May, 1884; Trevisan, I generi e le specie delle Batteriacee, Milan, 1889, 33.)

Staphylococcus liquefaciens aurantiacus Distaso. (Cent. f. Bakt., I Abt., Orig., *59*, 1911, 102.) From feces.

Staphylococcus muscae Glaser. (Amer. Jour. Hyg., *4*, 1924, 411.) Causes a fatal infection in house flies (*Musca domestica*). For a description of this species, see Bergey et al., Manual, 5th ed., 1939, 264.

Staphylococcus non pyogenes Savor. (Beitr. z. Geburtshilfe u. Gynäkol. v. Hegar, *2*, Heft 1, 1898; Abst. in Cent. f. Bakt., I Abt., *26*, 1899, 642.) From urino-genital tract.

Staphylococcus pharyngis Bergey et al. (Manual, 1st ed., 1923, 56.) Found in the human nasopharynx in acute catarrhal inflammation. For a description of this species, see Bergey et al., Manual, 5th ed., 1939, 265.

Staphylococcus putrificus Schottmüller. (Leitfaden f. d. Klinisch- Bakt. Kultur-Methoden, Berlin, Wien, 1923. Quoted from Weinberg, Nativelle and Prévot, Les Microbes Anaérobies, Paris, 1927, 1027.)

Staphylococcus pyogenes liquefaciens albus Hlava. (Sborník lékařský, II, Prague, 1887, 12 pp.; Abst. in Cent. f. Bakt., *2*, 1887, 688.) From small pox pustules.

Staphylococcus pyogenes tenuis Scheibe. (Inaug. Diss., München, 1889; see Cent. f. Bakt., *6*, 1889, 186.) From middle ear infections.

Staphylococcus roseus Tavel. (Quoted from Lehmann and Neumann, Bakt. Diag., 1 Aufl., *2*, 1896, 177.) Evidently identical with *Micrococcus roseus* Lehmann and Neumann or *Micrococcus roseo-fulvus* Lehmann and Neumann.

Staphylococcus salivarius Andrewes and Gordon. (35th Ann. Rept. Local Govt. Board London, 1905–06, 558.) From saliva. Probably *Micrococcus candidus* Cohn.

Staphylococcus ureae candidus Lundström. (Festschr. d. path.-anat. Inst. z. Andenken a. d. 250 jährige Bestehen d. finnländ. Univ. Helsingfors, 1890; abst. in Cent. f. Bakt., *9*, 1891, 672.) From urine. Probably *Micrococcus ureae* Cohn.

Staphylococcus ureae non pyogenes Barlow. (Arch. f. Dermat. u. Syph., 1893; Abst. in Cent. f. Bakt., *14*, 1893, 456.) From cases of cystitis.

Urococcus dowdeswelli Miquel. (Ann. de Micrographie, *5*, 1893, 209.) Ferments urea.

Urococcus van tieghemi Miquel (*loc. cit.*, 161). Ferments urea.

Genus II. **Gaffkya** *Trevisan.**

(Trevisan, Atti d. Accad. Fisio-Medico-Statistica in Milano, Ser. 4, *3*, 1885, 106; *Tetracoccus* Klecki, Cent. f. Bakt., *15*, 1894, 360; not *Tetracoccus* Orla-Jensen, The Lactic Acid Bacteria, Mém. Acad. Sci. Danemark, Sec. Sci., 8 sér, *5*, 1919, 154; *Tetradiplococcus* Bartoszewicz and Schwarzwasser, Cent. f. Bakt., II Abt., *21*, 1908, 614.) Named for Prof. Georg Gaffky, 1850–1918, Berlin.

Occur in the animal body and in special media as tetrads, while in ordinary culture media they occur in pairs and irregular masses. Aerobic to anaerobic. Gram-positive. Parasitic organisms.

The type species is *Gaffkya tetragena* (Gaffky) Trevisan.

Key to the species of genus **Gaffkya.**

I. Facultative aerobe.

1. *Gaffkya tetragena.*

II. Strict anaerobe.

2. *Gaffkya anaerobia.*

1. **Gaffkya tetragena** (Gaffky) Trevisan. (*Micrococcus tetragenus* Gaffky, Arch. f. Chirurg., *28*, Heft 3, 1883, 500; Trevisan, Atti d. Accad. Fisio-Medico-Statistica in Milano, Ser. 4, *3*, 1885, 106; *Micrococcus tetragenus septicus* Boutron, Thesis, Paris, 1893; Abst. in Cent. f. Bakt., *16*, 1894, 971; *Micrococcus tetragenus albus* Boutron, *ibid.*; *Merista septica* Hueppe, Principles of Bacteriology (Eng. trans.), 1899, 170; *Sarcina septica* Hueppe, *ibid.*; *Sarcina tetragena* Migula, Syst. d. Bakt., *2*, 1900, 225; *Merista tetragena* Vuillemin, Ann. Mycologie, Berlin, *11*, 1913, 525; *Staphylococcus tetragenus* Holland, Jour. Bact., *5*, 1920, 224; *Tetracoccus septicus* Neveu-Lemaire, Précis Parasitol. Hum., 5th ed., 1921, 18; *Pediococcus tetragenus* Pribram, Klassifikation der Schizomyceten, 1933, 46.) From Greek, *tetra* (*tetara*), four; M. L. *genes*, producing.

Spheres: 0.6 to 0.8 micron in size, with pseudocapsule (in body fluids) surrounding four of the elements showing typical tetrads. Gram-positive.

Gelatin colonies: Small, 1 to 2 mm. in diameter, white convex.

Gelatin stab: Thick, white surface growth. No liquefaction.

Agar colonies: Circular, white, smooth, glistening, entire. Reimann (Jour. Bact., *31*, 1936, 385) has described eleven colony form variants for this species.

Agar slant: White, moist, glistening.

Broth: Clear, with gray viscous sediment.

Litmus milk: Slightly acid.

Potato: White, viscid.

Indole not formed.

Nitrites not produced from nitrates.

Starch not hydrolyzed.

Ammonium salts not utilized.

Acid from glucose, lactose and glycerol.

No H_2S formed.

Aerobic, facultative.

Pathogenic for mice and guinea pigs; rabbits less susceptible.

Optimum temperature 37°C.

Source: Isolated from sputum in tuberculosis; also from air and skin.

Habitat: Mucous membrane of respiratory tract.

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* Revised by Prof. G. J. Hucker, N. Y. State Experiment Station, Geneva, New York March, 1943.

2. **Gaffkya anaerobia** (Choukévitch) Prévot. (*Tetracoccus anaerobius* Choukévitch, Ann. Inst. Past., *25*, 1911, 349; *Micrococcus tetragenes anaerobius* Hamm, Die puerperale Wundinfektion, Berlin, 1912; Prévot, Ann. Sci. Nat., Sér. Bot., *15*, 1933, 203.) From Greek, *an*, without; *aer*, air; *bios*, life.

Spheres: About 1.0 to 1.5 microns, occurring in tetrads, sometimes in groups of eight. Gram-positive.

Gelatin: No liquefaction.

Deep agar colonies: After 24 to 48 hours, small, grayish, 2 to 3 mm. in diameter. Abundant production of gas which breaks up the agar.

Broth: Poor growth. Slight sediment.

Milk: Unchanged.

Coagulated proteins not digested.

Optimum temperature 37°C. No growth at 22°C.

Non-pathogenic for guinea-pigs or rabbits.

Strict anaerobe.

Distinctive characters: Prefers acid media.

Source: Isolated from the female genital tract; isolated from the large intestine of a horse.

Habitat: Probably widely distributed in natural cavities of man and animals.

Appendix: The following species have been placed in the genus *Gaffkya* or in the genus *Tetracoccus*.

Gaffkya archeri Trevisan. (A black micrococcus, Archer, Quart. Jour. Microscop. Sci., 1874, 321; Trevisan, I generi e le specie delle Batteriacee, Milan, 1889, 27.)

Gaffkya grandis DeToni and Trevisan. (Microcoque des reins et des ulcéres syphilitiques de la peau, Babes, in Cornil and Babes, Les Bactér., 2nd ed., 1886, 782; DeToni and Trevisan, in Saccardo, Sylloge Fungorum, *8*, 1889, 1042.)

Gaffkya mendozae DeToni and Trevisan. (*Micrococcus tetragenus* and *Micrococcus tetragenus mobilis ventriculi* Mendoza, Cent. f. Bakt., *6*, 1889, 567; DeToni and Trevisan, in Saccardo, Sylloge Fungorum, *8*, 1889, 1043; *Planococcus tetragenus* Migula, Syst. d. Bakt., *2*, 1900, 269; *Micrococcus mendozae* Chester, Man. Determ. Bact., 1901, 84; *Sarcina tetragena* Winslow and Rogers, Jour. Inf. Dis., *3*, 1906, 545; *Planomerista ventriculi* Vuillemin, Ann. Mycolog., Berlin, *11*, 1913, 525.) Motile. Isolated from the contents of the stomach. Hucker (N. Y. State Exp. Sta. Tech. Bull. No. 102, 1924, 21) regards this as a synonym of *Gaffkya tetragena* Trevisan.

Gaffkya tardissima (Altana) Bergey et al. (*Tetragenus tardissimus* Altana, Cent. f. Bakt., I Abt., Orig., *48*, 1909, 42; Bergey et al., Manual, 2nd ed., 1925, 59.) From a natural infection of guinea pigs. See Manual, 5th ed., 1939, 269 for a description of this species.

Gaffkya verneti Corbet. (Organism No. 21, Denier and Vernet, La Caoutchouc, *17*, 1920, 10491; Corbet, Quart. Jour. Rubber Research Inst., Malaya, *2*, 1930, 143.) From the latex of the Para rubber tree (*Hevea brasiliensis*). For a description of this species, see Manual, 5th ed., 1939, 269.

Tetracoccus carneus halophilus Horowitz-Wlassowa. (Cent. f. Bakt., II Abt., *85*, 1932, 16.) Isolated from salted intestines (Wiener skins).

Tetracoccus casei Orla-Jensen. (The Lactic Acid Bacteria, 1919, 80.) From cheese. Probably identical with *Micrococcus freudenreichii* Guillebeau.

Tetracoccus mastitidis Orla-Jensen (*loc. cit.*, 81). From milk of a woman with mastitis. Orla-Jensen thinks this is identical with the staphylococcus that causes mastitis in cows, i.e., *Micrococcus pyogenes* var. *aureus* Zopf.

Tetracoccus mycodermatus Orla-Jensen (*loc. cit.*, 81). From Camembert cheese.

Genus III. **Sarcina** *Goodsir.**

(Goodsir, Edinborough Med. and Surg. Jour., 1842, 430; *Lactosarcina* Beijerinck, Arch. néerl. d. sci. exact., Ser. 2, *13*, 1908, 359; *Urosarcina* Miquel, Ann. Microg., *1*, 1888, 517; *Planosarcina* Migula, Arb. Bakt. Inst. Karlsruhe, *1*, 1894, 236; *Pseudosarcina* Löhnis, Handb. d. landwirtsch. Bakt., 1910, 449 (Pseudo-sarcina, Mazé, Compt. rend. Acad. Sci. Paris, *137*, 1903, 887); *Sporosarcina* Orla-Jensen, Cent. f. Bakt., II Abt., *22*, 1909, 340; *Paulosarcina* Enderlein, Sitzber. Gesell. Naturf., Berlin, 1917, 319; *Phacelium* Enderlein, *ibid.*, 319; *Zymosarcina* Smit, Die Gärungssarcinen. Pflanzenforschung, Heft 14, 1930, 26; *Butyrisarcina* Kluyver and Van Niel, Cent. f. Bakt., II Abt., *94*, 1936, 400; *Methanosarcina* Kluyver and Van Niel, *ibid.*) From Latin *sarcina*, packet, bundle.

Division occurs, under favorable conditions, in three planes, producing regular packets. Usually Gram-positive. Growth on agar abundant, usually with formation of yellow or orange pigment. Glucose broth slightly acid, lactose broth generally neutral. Gelatin frequently liquefied. Nitrites may or may not be produced from nitrates. Saprophytes and facultative parasites.

The type species is *Sarcina ventriculi* Goodsir.

Key to the species of genus Sarcina.

I. Microaerophilic to anaerobic.
  A. No growth without sugars. Do not produce methane. Sub-genus *Zymosarcina* Smit (Die Gärungssarcinen. Pflanzenforschung, Heft 14, 1930, 26).
    1. Cellulose reaction positive. Slow coagulation in litmus milk.
      1. *Sarcina ventriculi.*
    2. Cellulose reaction negative. Litmus milk not coagulated.
      2. *Sarcina maxima.*
  B. Does not utilize sugars. Produces methane. Sub-genus *Methanosarcina* Kluyver and van Niel (Cent. f. Bakt., II Abt., *94*, 1936, 400).
      3. *Sarcina methanica.*

II. Aerobic.
  A. No endospores present. Sub-genus *Sarcinococcus subgen. nov.*
    1. Not halophilic.
      a. Non-motile.
        b. Yellow pigment produced. Nitrites not produced from nitrates.
          c. Milk alkaline; coagulated.
            4. *Sarcina lutea.*
          cc. Milk alkaline; not coagulated.
            5. *Sarcina flava.*
        bb. Orange pigment produced. Nitrites produced from nitrates.
            6. *Sarcina aurantiaca.*
      aa. Motile.
            7. *Sarcina citrea.*
    2. Halophilic red chromogen.
            8. *Sarcina littoralis.*
  B. Endospores present. Motile. Sub-genus *Sporosarcina* Orla-Jensen (Cent. f. Bakt., II Abt., *22*, 1909, 340).
            9. *Sarcina ureae.*

*** Revised by Prof. Robert S. Breed, New York State Experiment Station, Geneva, New York, March, 1943.**

1. **Sarcina ventriculi** Goodsir. (Goodsir, Edinborough Med. and Surg. Jour., *57*, 1842, 430; *Merismopedia goodsirii* Husemann, De anim. et végét., 18—, 13; *Merismopedia ventriculi* Robin, Histoire des végét. parasites, 1853, 331; Anaerobic sarcina, Beijerinck, Proc. of Section of Sciences, Kon. Akad. v. Wetensch., Amsterdam, *7*, 1905, 580; *Zymosarcina ventriculi* Smit, Die Gärungssarcinen. Pflanzenforschung, Jena, Heft 14, 1930, 26; *Sarcina beijerincki* Prévot, Ann. Sci. Nat., Sér. Bot., *15*, 1933, 205.) From Latin, *ventriculus*, the stomach.

Description taken in part from Smit (*loc. cit.*).

Large spheres: 3.5 to 4.0 microns, occurring in packets of 8, 16, 32 or more elements. Non-motile. Gram-positive. Cellulose reaction positive.

Growth occurs only in sugar media, containing peptones.

Gelatin: No liquefaction.

Deep glucose agar colonies: Multi-lenticular, surrounded by a cloudy zone. Abundant gas.

Glucose agar slant: Round, whitish colonies, several millimeters in diameter.

Glucose broth: Abundant, flaky growth. Abundant gas. Acid. No turbidity.

Plain peptone water: No growth.

Sugar peptone water: Abundant growth. Gas. Indole not formed.

Milk: Slow growth. Acid and coagulation.

Coagulated proteins not attacked.

Acid and gas from glucose, fructose, sucrose, maltose, lactose and galactose. No acid from xylose, arabinose, raffinose, mannitol, dulcitol, salicin, starch, glycerin and inulin.

Neutral red broth changed to fluorescent yellow.

Utilizes peptones, wort and yeast water as sources of nitrogen. Cannot utilize amino acids or inorganic nitrogen.

Principal products of metabolism are carbon dioxide and ethyl alcohol.

Nitrites not produced from nitrates.

Non-pathogenic.

Optimum pH 1.5 to 5.0. Limits of pH 0.9 to 9.8.

Temperature relations: Optimum 30°C. Maximum 45°C. Minimum 10°C. Killed in ten minutes at 65°C.

Microaerophilic to anaerobic.

Source: Isolated from a diseased stomach.

Habitat: Garden soil, dust, sand, mud; the stomach.

2. **Sarcina maxima** Lindner. (Lindner, Die Sarcina-Organismen der Gärungsgewerbe. Inaug. Diss., Berlin, 1888, 54; Also abstract in Cent. f. Bakt., *4*, 1888, 427; *Zymosarcina maxima* Smit, Die Gärungssarcinen. Pflanzenforschung, Heft 14, 1930, 22; *Butyrisarcina maxima* Kluyver and van Niel, Cent. f. Bakt., II Abt., *94*, 1936, 400.) From Latin *maxima*, largest.

Description from Weinberg, Nativelle and Prévot, Les Microbes Anaérobies, 1937, 1030 and from Smit, *loc. cit.*

Large spheres: 4.0 to 4.5 microns, occurring in regular packets of 8, 16, 32 or more elements. Non-motile. Gram-positive.

Growth occurs only in sugar media, containing peptones.

Gelatin: No liquefaction.

Deep glucose agar colonies: Multi-lenticular. Abundant gas produced.

Glucose agar slant: Round, whitish colonies.

Glucose broth: Abundant growth, flaky, gaseous, marked acidification. Disagreeable butyric odor. No turbidity.

Sugar peptone water: Abundant growth, flaky, gaseous, followed by acidification.

Milk: Not coagulated.

Coagulated proteins not attacked.

Cellulose reaction negative.

Acid and gas from glucose, fructose, galactose, maltose, sucrose and lactose.

Neutral red broth changed to fluorescent yellow.

Utilizes peptones, yeast water or broth as source of nitrogen. Cannot utilize amino acids or inorganic nitrogen.

Principal products of metabolism are carbon dioxide, butyric and acetic acids.

Non-pathogenic.

Limits of pH 1.0 to 9.5.

Temperature relations: Optimum 30°C. Maximum 40°C. Minimum 15°C. Killed in twenty minutes at 55°C.

Microaerophilic to anaerobic.

Source: Isolated from fermenting malt mash.

Habitat: Acidified flour pastes, wheat bran; seldom in soils. Also intestinal contents of guinea pigs (Crecelius and Rettger, Jour. Bact., *46*, 1943, 10).

3. **Sarcina methanica** (Smit) Weinberg et al. (Methaansarcine, Söhngen, Inaug. Diss., Delft, 1906, 104; *Zymosarcina methanica* Smit, Die Gärungssarcinen. Pflanzenforschung, Heft 14, 1930, 25; *Methanosarcina methanica* Kluyver and Van Niel, Cent. f. Bakt., II Abt., *94*, 1936, 400; Barker, Arch. f. Mikrobiol., *7*, 1936, 420; Weinberg, Nativelle and Prévot, Les Microbes Anaérobies, 1937, 1032.) From M. L. *methanum*, methane; M. L. *methanicus*, related to methane.

Description from Weinberg, Nativelle and Prévot (*loc. cit.*) and Smit (*loc. cit.*).

Spheres: 2.0 to 2.5 microns, occurring in packets of 8 or more cocci. Non-motile. Gram-variable.

Growth in solutions of calcium acetate and possibly butyrate and inorganic ammonium salts. Carbon dioxide is needed for growth.

In acetate-agar (with addition of some H_2S and $NaHCO_3$): Colonies of 50 to 100 microns are formed, showing gas formation.

Cultural characters as yet unknown.

Peptones not attacked.

Cellulose reaction negative.

Utilizes ammonium salts as source of nitrogen. No organic nitrogen compounds utilized.

Carbohydrates not fermented. Ethyl alcohol is not fermented.

Principal products from the metabolism of calcium acetate and butyrate are methane, carbon dioxide and calcium carbonate.

Non-pathogenic.

Optimum temperature 35° to 37°C.

Strict anaerobe. Killed by a short contact with the air.

Distinctive characters: Utilizes ammonium salts and acyclic acids producing methane and carbonic acid.

Source: Sediment in methane fermentation (Weinberg et al.). Isolated from mud (Smit).

Habitat: Swamp waters and mud; fermenting sewage sludge.

4. **Sarcina lutea** Schroeter. (Kryptog. Flora v. Schlesien, *3*, 1, 1886, 154; also see Klein, Microorganisms and Disease, 1885, 43; Eisenberg, Bakt. Diag., 1 Aufl., Taf. 2, 1886; Flügge, Die Mikroorganismen, 2 Aufl., 1886, 179; Frankland and Frankland, Phil. Trans. London, *178*, B, 1888, 265.) From Latin *luteus*, yellow.

Spheres: 1.0 to 1.5 microns, showing packets in all media. Gram-positive.

Gelatin colonies: Circular up to 5 mm. in diameter, sulfur-yellow, sinking into the medium.

Gelatin stab: Slow infundibuliform liquefaction.

Agar colonies: Yellow, coarsely granular, circular, raised, moist, glistening, entire margin.

Agar slant: Sulfur to chrome yellow, smooth, soft.

Broth: Clear with abundant yellow sediment.

Litmus milk: Coagulated, becoming alkaline.

Potato: Sulfur to chrome yellow, raised; sometimes limited growth.

Slight indole formation.

Nitrites generally produced from nitrates.

No acid from glucose, lactose or sucrose.

Hydrogen sulfide is formed.

Aerobic.

Optimum temperature 25°C.

Habitat: Air, soil and water, skin surfaces.

5. **Sarcina flava** De Bary. (Vorlesungen über Bakterien, 1887, 151; *Sarcina liquefaciens* Frankland and Frankland, Philos. Trans. Roy. Soc. London, *178*, B, 1888, 267.) From Latin, *flavus*, yellow.

Spheres: 1.0 to 2.0 microns, occurring in packets of 16 to 32 cells. Gram-positive.

Gelatin colonies: Small, circular, yellowish.

Gelatin stab: Slowly liquefied.

Agar slant: Yellow streak.

Broth: Slowly becoming turbid with whitish, later yellowish sediment.

Litmus milk: Alkaline, not coagulated.

Potato: Yellow streak.

Indole not produced.

Nitrites not produced from nitrates.

Aerobic.

Optimum temperature 30° to 35°C.

Habitat: Air, water, soil.

6. **Sarcina aurantiaca** Flügge. (Die Mikroorganismen, 1886, 180; For description see Frankland and Frankland, Phil. Trans. Roy. Soc. London, *178*, *B*, 1888, 266; *Paulosarcina aurantiaca* Enderlein, Sitzungsber. Ges. Naturf. Freunde, Berlin, 1917, 319.) From M. L., *aurantiacus*, orange-colored.

Spheres developing packets in all media. Gram-positive.

Gelatin colonies: Small, circular, dark yellow, entire margin, sinking into the medium.

Gelatin stab: Infundibuliform liquefaction.

Agar slant: Slightly raised, orange yellow to orange red, soft, smooth.

Broth: Flocculent turbidity, with abundant sediment.

Litmus milk: Coagulation and digestion.

Potato: Raised, yellow-orange, glistening to dull, granular.

Slight indole formation.

Nitrites not produced from nitrates.

No H_2S produced.

Aerobic.

Optimum temperature 30°C.

Habitat: Air and water.

7. **Sarcina citrea** (Migula) Bergey et al. (*Micrococcus agilis citreus* Menge, Cent. f. Bakt., *12*, 1892, 52; *Planococcus citreus* Migula, Arb. bakt. Inst. Karlsruhe, *1*, Heft 1, 1894, 236; *Micrococcus agilis-citreus* Chester, Man. of Bact., 1901, 115; Bergey et al., Manual, 1st ed., 1923, 74.) From M. L. *citreus*, lemon-yellow.

Spheres: 0.6 to 0.8 micron, occurring singly, in pairs and in packets. Motile, possessing a single flagellum. Gram-positive.

Gelatin colonies: Small, circular, yellowish, entire, becoming citron-yellow to orange.

Gelatin stab: No liquefaction.

Agar colonies: Small, yellow, convex, entire, smooth, glistening.

Agar slant: Abundant, yellow, plumose, glistening, taking on an orange color with age.

Broth: Turbid.

Potato: Abundant, yellow growth.

Indole not formed.

Nitrites not produced from nitrates.

Aerobic.

Optimum temperature 25°C.

Habitat: Air.

8. **Sarcina littoralis** Poulsen. (Poulsen, Vidensk. Meddel. naturh. Foren. i Copenhagen, 1879–80, 231–254; *Sarcina morrhuae* Farlow, U. S. Fish Commission Report for 1878, 1880, 974; Micrococcus a, Høye, Bergens Museums Aarbog., No. 7, 2 Hefte, 1901, 39; *Micrococcus litoralis* Kellerman, Cent. f. Bakt., II Abt., *42*, 1915, 399.) From Latin, *litus* (*littus*) *-toris*, the sea shore; *-alis*, relating to.

The relationships of the following to each other and to *Sarcina littoralis* are not clear:

Erythroconis litoralis Oersted. (Naturh. Tidsskrift, *3*, 1840–41, 555; *Merismopedia litoralis* Rabenhorst, Flora Europ. Algarum, *2*, 1864–65, 57; *Sarcina littoralis* Winter in Rabenhorst, Kryptogamen-Flora, *1*, I Abt., 1884, 50; *Pediococcus litoralis* Trevisan, I generi e le specie delle Batteriacee, Milano, 1889, 28; *Lampropedia littoralis* De Toni and Trevisan, in Saccardo, Sylloge Fungorum, *8*, 1889, 1049.)

Coniothecium bertherandi Mégnin. (Revue Mycologique, *6*, 1884, 197.) Saccardo and Berlese (Atti. del R. Instituto Veneto, Ser. VI, Vol. 3) consider *C. bertherandi* to be identical with *Sarcina littoralis*, while Zopf (Die Spaltpilze, 2 Aufl., 1884, 73; 3 Aufl., 1885, 102) considers *C. bertherandi* a stage of *Beggiatoa roseo-persicina*.

Description taken from Lochhead (Can. Jour. Res., *10*, 1934, 280).

Spheres: 1.2 to 1.6 microns occurring singly, in pairs, in fours, in short chains, and in packets, the arrangement varying with medium, temperature, salt concentration and age of culture. Non-motile. Gram stain variable, with rather more positive than negative cells.

No growth in ordinary media.

Salt gelatin: Growth slow, with no liquefaction.

Starch media (20 per cent salt): Colonies usually 1 to 3 mm, round, entire, convex, with a waxy appearance, brick red with a pale border, color appearing gradually.

Starch media slants (20 per cent salt): Filiform, slightly raised, entire edge. Coral red in color. Slight decrease in shade as cultures age.

Liquid media: No growth.

Potato: In 20 per cent salt, scanty growth. Slight chalky pink development near the top.

Indole not formed.

Nitrates reduced to nitrites.

Diastatic action negative.

Aerobic, obligate.

Halophilic, obligate, 16–32 per cent salt. Optimum 20–24 per cent.

Optimum temperature 37°C.

Source: Isolated from seashore mud near Copenhagen.

Habitat: Sea water brine, or sea salt. Isolated from salted hides and salted fish.

The following is believed by Kellerman (*loc. cit.*) to be a variety of *Sarcina littoralis*:

Diplococcus gadidarum Beckwith. (Beckwith, Cent. f. Bakt., I Abt., Orig., *60*, 1911, 351; *Micrococcus litoralis gadidarum* Kellerman, Cent. f. Bakt., II Abt., *42*, 1915, 400; *Pediococcus gadidarum* Pribram, Klassification der Schizomyceten, 1933, 46.) From reddened salted codfish.

9. **Sarcina ureae** (Beijerinck) Löhnis. (*Planosarcina ureae* Beijerinck, Cent. f. Bakt., II Abt., 7, 1901, 52; Löhnis, Landwirtsch. bakteriol. Prakticum, 1911, 138; *Sporosarcina ureae* Kluyver and van Niel, Cent. f. Bakt., II Abt., *94*, 1936, 401.) From Greek, *urum*, urine; M. L., *urea*, urea.

Probable synonym: *Sarcina psychrocarterica* (Rubentschick) Bergey et al. (*Urosarcina psychrocarterica* Rubentschick, Cent. f. Bakt., II Abt., *64*, 1925, 168; *ibid.*, *66*, 1926, 161; *ibid.*, *67*, 1926, 167; *ibid.*, *68*, 1926, 327; Bergey et al., Manual, 3rd ed., 1930, 95.)

Spheres: 0.7 to 1.2 microns, occurring singly, in pairs and in packets. Atypical endospores present. Motile, possessing long peritrichous flagella. Gram-positive.

Gelatin colonies: Small, circular, flat, tough, yellowish.

Converts urea into ammonium carbonate.

Aerobic.

Optimum temperature 20°C. Resists heating to 80°C for 10 minutes.

Source: Isolated from urine.

Appendix: The following names appear in the literature, and are listed here chiefly for their historical interest.

Many are inadequately described, and probably many are synonyms.

Micrococcus aurantiacus Pagliani, Maggiora and Fratini. (Pagliani et al., 1887; *Pediococcus aurantiacus* Trevisan, I generi e le specie delle Batteriacee, Milan, 1889, 28; *Merismopedia aurantiaca* Maggioria, Giorn. Soc. ital. d'Igiene, *11*, 1889, 355; *Pediococcus maggiorae* De Toni and Trevisan, in Saccardo, Sylloge Fungorum, *8*, 1889, 1051.) From skin of the human foot.

Planosarcina samesii Migula. (Eine bewegliche Sarcine, Sames, Cent. f. Bakt., II Abt., *4*, 1898, 664; Migula, Syst. d. Bakt., *2*, 1900, V and 278; *Sarcina agilis* Matzuschita, Zeit. f. Hyg., *35*, 1900, 496.) From liquid manure. Probably identical with *Sarcina ureae* Löhnis.

Sarcina acidificans Migula. (Sarcina No. VIII, Adametz, Landwirtsch. Jahrb., *18*, 1889, 243; Migula, Syst. d. Bakt., *2*, 1900, 258.) From cheese. Winslow and Winslow (The Systematic Relationships of the Coccaceae, 1908, 235) regard this species as a variant of *Sarcina lutea* Schroeter.

Sarcina agilis Saito. (Jour. Coll. Science Imp. Univ. Tokyo, *23*, 1908, 68; abst. in Cent. f. Bakt., II Abt., *24*, 1909, 228.) From dust.

Sarcina alba Zimmermann. (Weisse Sarcina, Maschek, Bakt. Untersuch. d. Leitmeritzer Trinkwässer, 1887, 64; Zimmermann, Die Bakterien unserer Trink- u. Nutzwässer, Chemnitz, I Reihe, 1890, 90.) From water. Zimmermann reported the presence of spores; subsequent workers failed to observe spores, even when working with original cultures.

Sarcina alba var. *incana* Appel. (Ber. d. landw. Inst. Königsberg, Heft 5, 1900, 89; quoted from Löhnis, Cent. f. Bakt., II Abt., *18*, 1907, 146.) Frequently found in milk. Closely related to Adametz's Sarcinae Nos. VII, VIII and IX.

Sarcina albida Gruber. (Arb. bakt. Inst. Karlsruhe, *1*, Heft 3, 1895, 256.) From the stomach contents of a man with stomach cancer.

Sarcina alutacea Gruber (*loc. cit.*, 221). From leaven.

Sarcina aurea Macé. (Traité Pratique de Bact., 2nd ed., 1892, 371; not *Sarcina aurea* Henrici, see below.) From lung exudate. Possesses active oscillary motility, but no flagella.

Sarcina aurea Henrici. (Arb. bakt. Inst. Karlsruhe, *1*, Heft 1, 1894, 91; *Sarcina aurescens* Gruber, *ibid.*, Heft 3, 1895, 263.) From Swiss cheese. Winslow and Winslow (*loc. cit.*, 233) regard this species as a variant of *Sarcina flava* De Bary which has acquired certain fermentative powers.

Sarcina aurescens var. *mucosa* Jaiser; quoted from Pribram, Klassifikation der Schizomyceten, 1933, 44.

Sarcina bicolor Kern. (Arb. bakt. Inst. Karlsruhe, *1*, Heft 4, 1897, 505.) From the stomach of a woodpecker (*Picus major*). Winslow and Winslow (*loc. cit.*, 232) regard this species as identical with *Sarcina flava* De Bary.

Sarcina butyrica Migula. (Sarcina No. XI, Adametz, Landwirtsch. Jahrb., *18*, 1889, 244; Migula, Syst. d. Bakt., *2*, 1900, 240.) From cheese. Winslow and Winslow (*loc. cit.*, 233) regard this as a variant of *Sarcina flava* De Bary which has acquired certain fermentative powers.

Sarcina candida Lindner. (Die Sarcina-Organismen der Gährungsgewerbe, Inaug. Diss., Berlin, 1888, 43; Abst. in Cent. f. Bakt., *4*, 1888, 427.) From water reservoir of a brewery and from air in the vicinity of the brewery.

Sarcina canescens Stubenrath. (Stubenrath, in Lehmann and Neumann, Bakt. Diag., 1 Aufl., *2*, 1896, 143.) Stubenrath considered this a subspecies or variety of his *Sarcina equi* from which it differed only by its constant gray color on all culture media. Winslow and Winslow (*loc. cit.*, 232) regard this as identical with *Sarcina flava* De Bary.

Sarcina carnea Gruber. (Arb. bakt. Inst. Karlsruhe, *1*, Heft 3, 1895, 278.) From leaven.

Sarcina casei Migula. (Sarcina No. VII, Adametz, Landwirtsch. Jahrb., *18*,

1889, 242; Migula, Syst. d. Bakt., *2*, 1900, 239.) From cheese. Winslow and Winslow (*loc. cit.*, 233) regard this species as a variant of *Sarcina flava* De Bary which has acquired certain fermentative powers.

Sarcina caseolytica Stark and Scheib. (Jour. Dairy Sci., *19*, 1936, 212.) From butter.

Sarcina cervina Stubenrath. (Stubenrath, in Lehmann and Neumann, Bakt. Diag., 1 Aufl., *2*, 1896, 146.) From the stomach in a case of carcinoma.

Sarcina citrea Winslow and Winslow. (The Systematic Relationships of the Coccacceae, 1908, 234; not *Sarcina citrea* Bergey et al., Manual, 1st ed., 1923, 74.) This is the name given by Winslow and Winslow to their Type 2, the nitrate-reducing group of *Sarcina*.

Sarcina citrina Gruber. (Arb. bakt. Inst. Karlsruhe, *1*, Heft 3, 1895, 269.) From leaven. Winslow and Winslow (*loc. cit.*, 235) regard this species as identical with *Sarcina lutea* Schroeter.

Sarcina conjunctivae Bergey et al. (*Sarcina citrea conjunctivae* Verderame, Cent. f. Bakt., I Abt., Orig., *59*, 1911, 384; Bergey et al., Manual, 1st ed., 1923, 71.) From the conjunctiva. Gram-negative.

Sarcina devorans Kern. (Arb. bakt. Inst. Karlsruhe, *1*, Heft 4, 1897, 502.) From stomach contents of a sparrow (*Passer montanus*).

Sarcina equi Stubenrath. (Stubenrath, in Lehmann and Neumann, Bakt. Diag., 1 Aufl., *2*, 1896, 143.) Found frequently in the urine of horses. Very similar to *Sarcina lutea* according to Stubenrath, who names three subspecies or varieties: *Sarcina livido-lutescens*, *S. canescens* and *S. variabilis*. Winslow and Winslow (*loc. cit.*, 232) regard this species as identical with *Sarcina flava* De Bary.

Sarcina erythromyxa (Overbeck) Král. (*Micrococcus erythromyxa* Overbeck, Nova Acta der Leop.-Carol, *55*, No. 7, 1891; Král, Verzeichnis der abzugebenden Bak.) For a description of this species, see Zimmermann, Die Bakterien unserer Trink- und Nutzwässer, Chemnitz, II, 1894, 70. From water. Produces a red pigment.

Sarcina fimentaria Lehmann and Neumann. (Eine bewegliche Sarcine, Sames, Cent. f. Bakt., II Abt., *4*, 1898, 664; Lehmann and Neumann, Bakt. Diag., 2 Aufl., *2*, 1899, 146; *Planosarcina samesii* Migula, Syst. d. Bakt., *2*, 1900, V and 278; *Sarcina samesii* Matzuschita, Bakt. Diag., Jena, 1902, 300.) From liquid manure. Exhibits active motility with many long flagella. Pribram (Klassifikation der Schizomyceten, 1933, 45) regards this organism as identical with *Sarcina ureae* and *Sarcina mobilis*.

Sarcina flavescens Henrici. (Arb. bakt. Inst. Karlsruhe, *1*, Heft 1, 1894, 91.) From Swiss cheese. Winslow and Winslow (*loc. cit.*, 232) regard this species as identical with *Sarcina flava* De Bary.

Sarcina fulva Stubenrath. (Das Genus Sarcina, München, 1897; see Lehmann and Neumann, Bakt. Diag., 2 Aufl., *2*, 1899, 143.) Isolated many times from stomach contents and once from preputial smegma. Similar to *Sarcina pulmonum*.

Sarcina fusca Gruber. (Arb. bakt. Inst. Karlsruhe, *1*, Heft 3, 1895, 282.) From flour.

Sarcina fuscescens De Bary. (Vorlesungen über Bakterien, 2 Aufl., 1887, 181 and Botan. Centralb., 1887, 34. Reduced to a synonym of *Sarcina ventriculi* Goodsir by Migula, Syst. d. Bakt., *2*, 1900, 259.) From the contents of the stomach.

Sarcina gasoformans Gruber. (Arb. bakt. Inst. Karlsruhe, *1*, Heft 3, 1895, 270.) From leaven. Young cultures produce considerable gas.

Sarcina gigantea Kern. (Arb. bakt. Inst. Karlsruhe, *1*, Heft 4, 1897, 508.) From stomach contents of the starling (*Sturnus vulgaris*). The diameter of a cell is 2.05 to 2.1 microns. Winslow and Winslow (*loc. cit.*, 232) regard this species as identical with *Sarcina flava* De Bary.

Sarcina gigantea Petter. (Proc. Kon.

Akad. Wet. Amsterdam, *34*, 1931, 1417; Thesis, Utrecht, 1932; Compt. rend. Acad. Sci., Paris, *196*, 1933, 300.) From salted herring. Halophilic.

Sarcina hamaguchiae Saito. (Cent. f. Bakt., II Abt., *17*, 1906, 155.) From soy bean mash.

Sarcina incana Gruber (*loc. cit.*, 248). From leaven.

Sarcina incarnata Gruber. (*Loc. cit.*, 279; *Rhodococcus incarnatus* Winslow and Rogers, Jour. Inf. Dis., *3*, 1906, 545.) From leaven. Produces pink pigment.

Sarcina intermedia Gruber (*Loc. cit.*, 277). From leaven. Winslow and Winslow (*loc. cit.*, 235) regard this species as identical with *Sarcina lutea* Schroeter.

Sarcina intestinalis Zopf. (Die Spaltpilze, 3 Aufl., 1885, 55.) From the intestines of poultry.

Sarcina lactea Gruber. (*Loc. cit.*, 254; not *Sarcina lactea* Bergey et al., Manual, 1st ed., 1923, 73.) From leaven.

Sarcina lactis Chester. (No. 45, Conn, Storrs Agr. Exp. Sta. Rept., 1894, 79; Chester, Man. Determ. Bact., 1901, 111.) From fermented milk (matzoon). Winslow and Winslow (*loc. cit.*, 232) regard this species as identical with *Sarcina flava* De Bary.

Sarcina lactis acidi Conn, Esten and Stocking. (Storrs Agr. Exp. Sta. Ann. Rept., 1907, 125.) From milk.

Sarcina lactis albus Conn, Esten and Stocking (*loc. cit.*, 124). From milk.

Sarcina lactis aurantiaca Conn, Esten and Stocking (*loc. cit.*, 125). From milk.

Sarcina lactis lutea Conn, Esten and Stocking (*loc. cit.*, 124). From milk.

Sarcina lembkei Migula. (No. 24, Lembke, Arch. f. Hyg., *26*, 1896, 316; Migula, Syst. d. Bakt., *2*, 1900, 241.) From the intestine. Winslow and Winslow (*loc. cit.*, 232) regard this species as identical with *Sarcina flava* De Bary.

Sarcina liquefaciens Frankland and Frankland. (Phil. Trans. Royal Soc. London, *178*, B, 1888, 267.) From dust. Also found in cheese by Henrici (Arb. bakt. Inst. Karlsruhe, *1*, Heft 1, 1894, 95). Winslow and Winslow (*loc. cit.*, 232) regard this species as identical with *Sarcina flava* De Bary.

Sarcina livida Gruber (*loc. cit.*, 297). From leaven. Winslow and Winslow (*loc. cit.*, 235) regard this species as identical with *Sarcina lutea* Schroeter.

Sarcina livido-lutescens Stubenrath. (Stubenrath, in Lehmann and Neumann, Bakt. Diag., 1 Aufl., *2*, 1896, 143; *Sarcina lutescens* Chester, Man. Determ. Bact., 1901, 112.) From stools in a case of enteritis. Stubenrath regards this as a subspecies or variety of his *Sarcina equi*.

Sarcina loewenbergii Macé. (Une sarcine pathogène, Loewenberg, Ann. Inst. Past., *13*, 1899, 358; Macé, Traité Pratique de Bact., 4th ed., 1901, 464.) From the nasal cavity in a case of ozena. Probably a strongly slime-forming variety of *Sarcina tetragena*, according to Lehmann and Neumann, Bakt. Diag., 5 Aufl., *2*, 1912, 206. Also see Galli-Valerio, Cent. f. Bakt., I Abt., Orig., *47*, 1908, 177, for discussion.

Sarcina luteola Gruber (*loc. cit.*, 265). From leaven. Winslow and Winslow (*loc. cit.*, 235) regard this species as identical with *Sarcina lutea* Schroeter.

Sarcina marginata Gruber (*loc. cit.*, 268). From leaven. Winslow and Winslow (*loc. cit.*, 235) regard this as identical with *Sarcina lutea* Schroeter.

Sarcina meliflava Gruber (*loc. cit.*, 272). From flour. Winslow and Winslow (*loc. cit.*, 235) consider this identical with *Sarcina lutea* Schroeter.

Sarcina minuta De Bary. (Vorlesungen über Bakterien, 1 Aufl., 1885; Eng. trans., 2nd ed., 1887, 117 and 185.)

Sarcina mirabilis Kern. (Arb. bakt. Inst. Karlsruhe, *1*, Heft 4, 1897, 506.) From intestine of the yellow-hammer (*Emberiza citrinella*) and a dove (*Columba oenas*). Winslow and Winslow (*loc. cit.*, 232) consider this species identical with *Sarcina flava* De Bary.

Sarcina mobilis Maurea. (Cent. f. Bakt., *11*, 1892, 228; *Planosarcina mobilis* Migula, Arb. bakt. Inst. Karlsruhe, *1*, 1894, 236; *Micrococcus mobilis* Dyar, Ann. N. Y. Acad. Sci., *8*, 1895, 353.) From old ascitic fluid. Motile, each cell with two short flagella.

Sarcina mucosa Sauerbeck. (Cent. f. Bakt., I Abt., Orig., *50*, 1909, 289.) From pulmonary sputum. Probably a slime-forming variety of *Sarcina tetragena*, according to Lehmann and Neumann, Bakt. Diag., 5 Aufl., *2*, 1912, 206.

Sarcina nivea Henrici. (Arb. bakt. Inst. Karlsruhe, *1*, Heft 1, 1894, 88.) From cheese.

Sarcina olens Henrici (*loc. cit.*, 94). From Camembert cheese. Winslow and Winslow (*loc. cit.*, 232) regard this species as identical with *Sarcina flava* De Bary.

Sarcina orangea Cahanesco. (Ann. Inst. Past., *15*, 1901, 856.) From vagina of a dog.

Sarcina paludosa Schroeter. (Schroeter, in Cohn, Kryptog. Flora v. Schlesien, *3*, I, 1886, 153.) From the waste water of a sugar factory. Not cultivated.

Sarcina persicina Gruber (*loc. cit.*, 281). From leaven.

Sarcina pseudogonorrhoeae Lehmann and Neumann. (Eine neue Sarcina, Nagano, Cent. f. Bakt., I Abt., Orig., *32*, 1902, 327; Lehmann and Neumann, Bakt. Diag., 4 Aufl., *2*, 1907, 212; *Sarcina naganoi* Macé, Traité Pratique de Bact., 6th ed., *1*, 1912, 631.) From pus.

Sarcina pulchra Henrici (*loc. cit.*, 89). From cheese.

Sarcina pulmonum Hauser. (Lungensarcine, Virchow, Arch. f. path. Anat., *9*, 1856, 557; Hauser, Deutsch. Arch. f. klin. Medizin, *42*, 1887, 127; *Sarcina virchowii* Trevisan, Atti dell' Accad. Fisio-Medico-Statistica di Milano, Ser. IV, *3*, 1885, 119.) From the sputum of a patient with phthisis. Motile (Lehmann and Neumann, Bakt. Diag., 2 Aufl., *2*, 1899, 141). Hauser says this sarcina forms endogenous spores which may be demonstrated by Neisser's method of staining, and which have great resistance to heat. When cultivated in urine, it causes ammoniacal fermentation of the urea. Regarded by Jan Smit (personal communication, 1939) as identical with *Sarcina ureae*.

Sarcina radiata Kern (*loc. cit.*, 53). From stomach and intestines of the rock dove (*Columba livia*) and a sparrow (*Passer montanus*). Winslow and Winslow (*loc. cit.*, 232) regard this as identical with *Sarcina flava* De Bary.

Sarcina rosacea Migula. (*Sarcina rosea* (Schroeter) Lindner, Inaug. Diss., Berlin, 1888, 45; Migula, Syst. d. Bakt., *2*, 1900, 263.) Found frequently in dust and water. Lindner believed his culture to be *Sarcina rosea* Schroeter.

Sarcina rubra Migula. (Eine rothe Sarcine, Menge, Cent. f. Bakt., *6*, 1889, 596; Migula, Syst. d. Bakt., *2*, 1900, 261.) From red milk.

Sarcina schaudinni (Wolff) Pribram. (*Planosarcina schaudinni* Wolff, Cent. f. Bakt., II Abt., *18*, 1907, 9; Pribram, Klassifikation der Schizomyceten, 1933, 45.) From rotten places on potatoes. A motile coccus with long flagella.

Sarcina solani Reinke and Berthold. (Die Zersetzung der Kartoffel durch Pilze, Berlin, 1879; see O. Appel in Lafar, Handbuch der Technischen Mykologie, *2*, 1905–08, 350.) Found in wet rotting of potatoes.

Sarcina striata Gruber (*loc. cit.*, 271). From flour. Winslow and Winslow (*loc. cit.*, 235) regard this species as identical with *Sarcina lutea* Schroeter.

Sarcina subflava Ravenel. (Memoirs Nat. Acad. Sci., *8*, 1896, 10.) From soil.

Sarcina sulfurea Henrici (*loc. cit.*, 90). From cheese. Winslow and Winslow (*loc. cit.*, 235) consider this species identical with *Sarcina lutea* Schroeter.

Sarcina superba Henrici (*loc. cit.*, 93). From cheese. Winslow and Winslow (*loc. cit.*, 232) regard this species as identical with *Sarcina flava* De Bary.

Sarcina symbiotica Pribram. (Eine gelbe Sarcina, Gropenfiesser, Cent. f.

Bakt., II Abt., *61*, 1925, 495; Pribram, Klassifikation der Schizomyceten, 1933, 45.) Lives symbiotically with cockroaches.

Sarcina thermodurica Wainess and Parfitt. (Jour. Bact., *40*, 1940, 157.) From milking machines and other dairy farm utensils. Resists pasteurization temperatures.

Sarcina thermophila Bargagli-Petrucci. (Nuov. Giorn. Bot. Ital., *20*, 1913; Abst. in Cent. f. Bakt., II Abt., *43*, 1915, 294.) From the borax-yielding waters of Tuscany. Grows at temperatures up to 75°C.

Sarcina urinae Welcker. (*Sarcina renis* Hepworth, Microscop. Jour., *5*, 1857, 1; Welcker, in Henle and Pfeffer, Ztschr. f. rat. Med., 3 Ser., *5*, 1859, 199; *Merismopedia urinae* Rabenhorst, Flor. europ. algarum, *2*, 1865, 59.) Observed in the bladder. See below, *Sarcina welckeri*.

Sarcina variabilis Stubenrath. (Stubenrath, in Lehmann and Neumann, Bakt. Diag., 1 Aufl., *2*, 1896, 143.) From gastric contents. May be considered a subspecies of *Sarcina equi* Stubenrath. Winslow and Winslow (*loc. cit.*, 232) regard this as identical with *Sarcina flava* De Bary.

Sarcina variegata Pansini. (Arch. f. path. Anat., *122*, 1890, 459.) Found in sputum from cases of influenza.

Sarcina velutina Gruber (*loc. cit.*, 275). From leaven. Winslow and Winslow (*loc. cit.*, 235) consider this species identical with *Sarcina lutea* Schroeter.

Sarcina vermicularis Gruber (*loc. cit.*, 253). From wheat flour.

Sarcina vermiformis Gruber (*loc. cit.*, 266). From leaven. Winslow and Winslow (*loc. cit.*, 235) consider this species identical with *Sarcina lutea* Schroeter.

Sarcina viridis flavescens Rosenthal. (Inaug. Diss., Erlangen, 1893; Abst. in Cent. f. Bakt., *16*, 1894, 1024.) From the oral cavity.

Sarcina welckeri Rossmann. (Rossman, Ueber Urinsarcina, Flora, *40*, 1857, 641; *Merismopedia welckeri* Rabenhorst, Flora europaea, Alg. II, 1865, 58.) From the urinary bladder.

Urosarcina dimorpha Beijerinck. (Cent. f. Bakt., II Abt., *7*, 1901, 53.) Reported to form spores. Non-motile. From garden earth.

FAMILY VI. NEISSERIACEAE PRÉVOT.*

(Ann. Sci. Nat., Sér. Bot., *15*, 1933, 119.)

Cells spherical, in pairs or in masses. Non-motile. Gram-negative. Pigment formation rare. The family contains aerobic and anaerobic species. Some grow poorly or not at all without mammalian body fluids. Optimum temperature 37°C. All known species are parasitic.

Key to the genera of family **Neisseriaceae.**

I. Occurring in pairs, with adjacent sides usually flattened. Aerobes, facultative anaerobes and anaerobes. Approximately 1 micron in diameter.
Genus I. *Neisseria*, p. 295.

II. Occurring in masses, rarely in pairs. Anaerobes. Less than .5 micron in diameter.
Genus II. *Veillonella*, p. 302.

Genus I. Neisseria *Trevisan.*

(Trevisan, Atti della Accademia Fisio-Medico-Statistica in Milano, Ser. 4, *3*, 1885, 105; *Gonococcus* Lindau (?), Just's Bot. Jahresber., I Abt., Orig., *26*, 1898, 100.) Named for Dr. Albert Neisser who discovered the organism causing gonorrhoea in 1879.

Paired, Gram-negative cocci with adjacent sides flattened. Four of the eleven species produce yellow pigment. Aerobic and anaerobic species occur. Growth on standard media may be poor. Biochemical activities are limited. Few carbohydrates are utilized. Indole is not produced. Nitrates are not reduced. Catalase is produced abundantly. Parasites of mammals so far as known.

The type species is *Neisseria gonorrhoeae* Trevisan.

Key to the species of genus **Neisseria.**

I. Aerobes, facultative anaerobes.
  A. Grow best on special culture media or on plain agar containing blood, blood serum or similar enrichment fluids, especially with added glucose. Grow best at 35° to 37°C; no growth below 25° or above 40°C. Not chromogenic.
    1. Acid from glucose, not from maltose. Growth anaerobically.
    1. *Neisseria gonorrhoeae.*
    2. Acid from glucose and maltose. No growth anaerobically.
    2. *Neisseria meningitidis.*
  B. Grow well on ordinary culture media. Grow well at 22°C.
    1. Non-chromogenic.
      a. Moist colonies on agar. No action on glucose, sucrose or mannitol.
      3. *Neisseria catarrhalis.*
      aa. Dry crumbly colonies on agar. Acid from glucose and sucrose; but not from mannitol.
      4. *Neisseria sicca.*

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* Revised by Prof. E. G. D. Murray, McGill University, Montreal, P.Q., Canada in consultation with Dr. Sara E. Branham, United States Public Health Service, Washington, D. C., June, 1938; further revision, August, 1943. Descriptions of anaerobic species reviewed by Dr. Ivan C. Hall, New York City, January, 1944.

2. Chromogenesis best seen on Löffler's serum.
    a. Acid from fructose.
        b. Acid from sucrose.
            5. *Neisseria perflava.*
        bb. No acid from sucrose.
            6. *Neisseria flava.*
    aa. No acid from fructose.
        b. Acid from glucose.
            7. *Neisseria subflava.*
        bb. No acid from glucose.
            8. *Neisseria flavescens.*

II. Anaerobes.
  A. Gas produced from peptone broth.
            9. *Neisseria discoides.*
  B. No gas produced.
    1. Odor of rancid butter.
            10. *Neisseria reniformis.*
    2. No rancid odor.
            11. *Neisseria orbiculata.*

1. **Neisseria gonorrhoeae** Trevisan. (Micrococcus der Gonorrhoe, Neisser, Vorl. Mitteil., Cent. f. Medicinische Wissenschaft, *17*, 1879, 497; Trevisan, Atti della Accademia Fisio-Medico-Statistica in Milano, Ser. 4, *3*, 1885, 105.) From Greek, *gonorrhoea*, flux of semen; M.L. genitive of gonorrhoea.

Synonyms: Gonococcus, Diplococcus der Gonorrhoe, Bumm, Der Mikroorganismen der gonorrhoischen Schleimhauterkrankung, Weisbaden, 1885, 16; *Merismopedia gonorrhoeae* Zopf, Die Spaltpilze, 1885, 54; *Micrococcus gonorrhoeae* Flügge, Die Mikroorganismen, 1886, 156; *Micrococcus gonococcus* Schroeter, in Cohn, Kryptog. Flora v. Schlesien, *3*, I, 1886, 147; *Diplococcus gonorrhoeae* Lehmann and Neumann, Bakt. Diag., 1 Aufl., *2*, 1896, 150; *Micrococcus gonorrhoeae* Lehmann and Neumann, *ibid.*, 4 Aufl., *2*, 1907, 212.

Spheres: 0.6 to 1.0 micron, occurring singly and in pairs, the sides flattened where they are in contact. Gram-negative.

Grows only on media with the addition of body fluids (blood, ascites, etc.), or other specially prepared media.

Colonies are small, transparent, eventually (2 to 4 days) developing a lobate margin, grayish-white with a pearly opalescence by transmitted light. Larger colonies on special media.

Acid from glucose. No acid from maltose, fructose, sucrose and mannitol.

Optimum temperature 37°C. No growth below 25° or above 40°C.

Aerobic to facultative anaerobic. Many strains develop more readily with increased CO_2 tension.

Common name: Gonococcus.

Source: Originally found in purulent venereal discharges. Also found in blood, conjunctiva, joints and cerebrospinal fluid.

Habitat: The cause of gonorrhoea and other infections of man. Not found in other animals.

2. **Neisseria meningitidis** (Albrecht and Ghon) Holland. (*Diplokokkus intracellularis meningitidis* Weichselbaum, Fortschr. d. Med., *5*, 1887, 583; *Neisseria weichselbaumii* Trevisan, I generi e le specie delle Batteriacee, 1889, 32; not *Diplococcus intracellularis* Jaeger, Ztschr. f. Hyg., *19*, 1895, 353; not *Tetracoccus intracellularis* Jaeger, *ibid.*, 368; not *Streptococcus intracellularis* Lehmann

and Neumann, Bakt. Diag., 1 Aufl., *2*, 1896, 132; *Micrococcus intracellularis* Migula, Syst. d Bakt., *2*, 1900, 189; *Micrococcus meningococcus cerebrospinalis* Albrecht and Ghon, Wiener klin. Wochnschr., *14*, 1901, 988; not *Streptococcus weichselbaumii* Chester, Man. Determ. Bact., 1901, 64; not *Meningococcus intracellularis* Jaeger, Cent. f. Bakt., I Abt., Orig., *33*, 1903, 23; *Micrococcus meningitidis* Albrecht and Ghon, Cent. f. Bakt., I Abt., Orig., *33*, 1903, 498; *Diplococcus intracellularis* Weichselbaum, Cent. f. Bakt., I Abt., Orig., *33*, 1903, 511; *Micrococcus intracellularis meningitidis* de Bettencourt and França, Ztschr. f. Hyg., *46*, 1904, 464; *Diplococcus meningitidis*, *ibid.*, 495; Holland, Jour. Bact., *5*, 1920, 224; *Neisseria intracellularis-meningitidis* Holland, *ibid.*, 224; *Neisseria intracellularis* Holland, *ibid.*, 224; see also Elser and Huntoon, Jour. Med. Res., *20* (N. S. *15*), 1909, 371 and Murray, Med. Res. Council, London, Special Report Series No. 124, 1929 for detailed studies of the group.) From Greek, *meninx*, *meninges*, a membrane, a membrane covering the brain; M. L. genitive of *meningitis*, an inflammation of the meninges.

The binomial, *Neisseria intracellularis*, used in previous editions of the Manual has proved confusing because the names *Micrococcus intracellularis*, *Diplococcus intracellularis* and *Streptococcus intracellularis*, have been used loosely for unrelated organisms. *Neisseria weichselbaumii* has been so rarely and loosely used that any attempt to introduce it now is inadvisable despite rights of priority. The equally available name, *Neisseria meningitidis*, has therefore been adopted to avoid further confusion. It has the obvious advantage of association with the common name, meningococcus, which has been so frequently used in the literature.

In 1898, Councilman, Mallory and Wright (Epidemic Cerebrospinal Meningitis and its Relation to Other Forms of Meningitis, Boston, 1898) definitely established the Gram-negative coccus as the cause of epidemic meningitis and clarified the confusion created because Jaeger regarded the coccus that he isolated (see *Diplococcus crassus* von Lingelsheim) as identical with *Neisseria meningitidis.*

Spheres: 0.6 to 0.8 micron in diameter, occasionally larger, occurring singly, in pairs with adjacent sides flattened, or occasionally in tetrads. Gram-negative.

Good growth is obtained on media containing blood, blood serum and other enrichment fluids with added glucose. Best growth on special media.

Blood agar plates are generally employed to isolate the organism. The colonies are small, slightly convex, transparent, glistening. Colonies large on special media.

Older cultures may show growth on neutral agar or glucose agar, properly prepared. Frequent transplantation is necessary to keep the organism alive in recently isolated strains; older strains survive for one month or longer at 37°C and for years on special media.

Acid from glucose and maltose. No acid from fructose, sucrose and mannitol.

Nitrites not produced from nitrates (Branham).

Optimum temperature 37°C. No growth at 22° or at 40°C.

Aerobic, no growth anaerobically.

Common name: Meningococcus.

Source: Originally found in cerebrospinal fluid. Also found in nasopharynx, blood, conjunctiva, pus from joints, petechiae in skin, etc.

Habitat: Nasopharynx of man, not found in other animals. Cause of epidemic cerebrospinal fever (meningitis).

Four main varieties or types of *Neisseria meningitidis* have been differentiated by Gordon and Murray (Jour. Roy. Army Med. Corps, *25* (*2*), 1915, 423) and by others on the basis of agglutination reactions with immune serums.

3. **Neisseria catarrhalis** (Frosch and Kolle) Holland. (*Micrococcus catarrhalis* Frosch and Kolle, in Flügge, Die Mikroorganismen, 3 Aufl., *2*, 1896, 154; *Diplococcus pharyngis communis* von Lingelsheim, Klin. Jahrb., *15*, 1906, 408; Holland, Jour. Bact., *5*, 1920, 224.) From Greek, *catarrh*, a running down.

Spheres: 0.6 to 0.8 micron in diameter, occurring singly or in pairs with adjacent sides flattened, occasionally in fours. Gram-negative.

Agar colonies: Small, circular, grayish white to dirty white, with erose margins.

Broth: Turbid, often with slight pellicle.

No acid from any of the carbohydrates.

Optimum temperature 37°C. Grows well at 22°C.

Aerobic, facultative.

Source: Nasopharynx, saliva and respiratory tract.

Habitat: Human mucous membrane of the respiratory tract. Often associated with other organisms in inflammations of the mucous membrane.

Note: Topley and Wilson (Prin. of Bact., 1931, 349) state that *Neisseria pharyngis cinerea* (*Micrococcus pharyngis cinereus* von Lingelsheim, Klin. Jahrb., *15*, 1906, 373) resembles *Neisseria catarrhalis* so closely that it should probably be regarded as a variety of this species.

4. **Neisseria sicca** (von Lingelsheim) Bergey et al. (*Diplococcus pharyngis siccus* von Lingelsheim, Klin. Jahrb., *15*, 1906, 409; *Diplococcus siccus* von Lingelsheim, Ztschr. f. Hyg., *59*, 1908, 476; *Micrococcus pharyngis siccus* Kutscher, in Kolle and Wassermann, Handb. d. Path. Mikroorganismen, 2 Aufl., *4*, 1912, 603; *Micrococcus pharyngis-siccus* Holland, Jour. of Bact., *5*, 1920, 224; *Neisseria pharyngis-sicci* (sic) Holland, *ibid.*; Bergey et al., Manual, 1st ed., 1923, 43.) From Latin, *sicca*, dry.

Spheres: 0.6 to 0.8 micron in diameter, occurring singly and in pairs with adjacent sides flattened. Gram-negative.

Blood agar colonies: Grayish, somewhat dry, crumbling when an effort is made to remove them.

Ascitic agar colonies: Small, very firm and adherent to medium, becoming corrugated on the surface.

The organisms precipitate spontaneously when suspended in normal salt solution.

Acid from glucose, fructose, maltose and sucrose. No acid from mannitol.

Optimum temperature 37°C. Grows at 22°C.

Aerobic, facultative.

Source: Nasopharynx, saliva and sputum.

Habitat: Mucous membrane of the respiratory tract of man.

5. **Neisseria perflava** Bergey et al. (Chromogenic group I, Elser and Huntoon, Jour. Med. Res., *20* (N. S. *15*), 1909, 415; Bergey et al., Manual, 1st ed., 1923, 43.) From Latin *per*, very and *flavus*, yellow.

Spheres: 0.6 to 0.8 micron, occurring singly and in pairs with adjacent sides flattened. Gram-negative.

Glucose agar colonies: Small, circular, slightly raised, greenish-gray by reflected light, and greenish-yellow and semi-opaque by transmitted light. The surface is smooth, glistening. The growth is adherent to the medium. Chromogenesis best seen on Löffler's blood serum medium.

Ascitic agar colonies: Like those on glucose agar.

Acid from glucose, maltose, fructose, sucrose and mannitol.

Optimum temperature 37°C. Grows at 22°C.

Aerobic, facultative.

Source: Nasopharynx, saliva and sputum.

Habitat: Mucous membrane of respiratory tract of man.

6. **Neisseria flava** Bergey et al. (*Diplococcus pharyngis flavus I* and possibly

Diplococcus pharyngis flavus II, von Lingelsheim, Klin. Jahrb., *15*, 1906, 409; *Diplococcus flavus I* and possibly *Diplococcus flavus II*, v. Lingelsheim, Zeitschr. f. Hyg., *59*, 1908, 476; *Micrococcus pharyngis flavus I* and possibly *Micrococcus pharyngis flavus II*, Lehmann and Neumann, Bakt. Diag., 7 Aufl., *2*, 1927, 259; Chromogenic group II, Elser and Huntoon, Jour. Med. Res., *20* (N. S. *15*), 1909, 415; Bergey et al., Manual, 1st ed., 1923, 43.) From Latin *flavus*, yellow.

Spheres: 0.5 to 0.8 micron, occurring singly and in pairs with adjacent sides flattened. Gram-negative.

Glucose agar colonies: Small, circular, slightly raised, greenish-gray by reflected light and greenish-yellow by transmitted light. . Growth not adherent to medium. Surface colony is smooth with numerous, rather coarse crumbs in center. Margin entire, or rarely slightly irregular. Chromogenesis best seen on Löffler's blood serum medium.

Ascitic agar colonies: Like those on glucose agar.

Acid from glucose, fructose and maltose. No acid from sucrose or mannitol.

Optimum temperature 37°C. Grows at 22°C.

Source: Nasopharynx, cerebro-spinal fluid in cases of meningitis (very rare).

Habitat: Mucous membrane of respiratory tract.

7. **Neisseria subflava** Bergey et al. (Chromogenic group III, Elser and Huntoon, Jour. Med. Research, *20* (N.S. *15*), 1909, 415; Bergey et al., Manual, 1st ed., 1923, 44.) From Latin *sub*, less and *flavus*, yellow.

Spheres: 0.6 to 0.8 micron, occurring singly and in pairs with adjacent sides flattened. Gram-negative.

Glucose agar colonies: Small, slightly raised, pale greenish-yellow, especially on primary culture.

Acid from glucose and maltose. No acid from fructose, sucrose or mannitol.

Agglutinates in normal rabbit serum.

Optimum temperature 37°C. Little or no growth at 22°C.

Aerobic, facultative.

Easily confused with *Neisseria meningitidis*.

Source: Nasopharynx.

Habitat: Mucous membrane of the respiratory tract of man.

8. **Neisseria flavescens** Branham. (U. S. Public Health Service, Pub. Health Repts., *45*, 1930, 845.) From Latin *flavescens*, becoming yellow.

Biscuit-shaped cocci occurring in flattened pairs. Giant forms common. Gram-negative.

Glucose agar: Poor growth.

Blood agar: Good growth, colonies less moist than those of the meningococcus. Golden yellow pigment. Greenish-yellow on Löffler's blood serum medium.

Semisolid agar: Good growth.

No acid from any of the carbohydrates.

Optimum temperature 37°C.

Aerobic, facultative.

Serologically homogeneous group.

Source: Cerebro-spinal fluid in cases of meningitis.

Habitat: Probably mucous membrane of respiratory tract of man.

Note: Wilson and Smith (Jour. Path. and Bact., *31*, 1928, 597) do not regard differences in sugar fermentations, chromogenesis, appearance of colonies, etc. sufficiently constant to warrant the separation of the species *Neisseria catarrhalis*, *N. flava*, *N. cinerea*, *N. mucosa* and *N. sicca*. They recommend that all be grouped under a single species known as *Neisseria pharyngis* (*Diplococcus pharyngis*).

9. **Neisseria discoides** Prévot. (Ann. Sci. Nat., Sér. Bot., *15*, 1933, 106.) From Greek, *discoeides*, discus shaped; Latin adj., disk-shaped.

Spheres: 0.6 to 0.7 micron, occurring in pairs or tetrads. Gram-negative.

Gelatin: No liquefaction.

Deep agar colonies: Lenticular, up to 1 mm in diameter. Grows in a narrow disk about 1 cm below the surface. Gas produced.

Broth: Turbid. Fine granular precipitate. Slight rancid odor and inflammable, explosive gas produced.

Peptone water: Gas produced.

Indole not formed.

No action on milk.

Coagulated proteins not digested.

Carbohydrates not attacked.

Hydrogen sulfide not produced.

Neutral red glucose broth: Becomes pink, but no further change.

Optimum pH 7.0 to 8.0.

Temperature relations: Optimum 37°C. No growth at 28°C. Killed in half an hour at 60°C.

Non-pathogenic.

Strict anaerobe.

Distinctive characters: Colonies grow in narrow zone 1 cm below the surface of an agar stab; gas produced from peptones.

Source: Isolated from bronchial mucus, respiratory system; dental and tonsillary focal infections.

Habitat: Buccal cavity (human) and probably also in other warm-blooded animals.

10. **Neisseria reniformis** (Cottet) Prévot. (*Diplococcus reniformis* Cottet, Compt. rend. Soc. Biol., *52*, 1900, 421; *Micrococcus reniformis* Oliver and Wherry, Jour. Inf. Dis., *28*, 1921, 341; Prévot, Ann. Sci. Nat., Sér. Bot., *15*, 1933, 102.) From Latin, *ren* (*renes*), kidney; *-formis*, form, i.e. kidney-shaped.

Spheres: 0.8 to 1.0 micron, bean-shaped, occurring in pairs. Gram-negative.

Gelatin: No liquefaction.

Deep agar colonies: Appear in 24 to 48 hours; at first punctiform, then lenticular; small, 0.3 to 0.5 mm. No gas produced.

Agar slant: Minute, bluish-white, dewdrop colonies.

Broth: Turbid in 24 hours; flocculent precipitate rapidly formed, clearing the medium. No gas produced, but a rancid odor is present.

Peptone water: Very meagre growth. Traces of indole.

Milk: Unchanged.

Coagulated proteins not digested.

Slight amount of acid from glucose by one strain only.

Optimum pH 7.0. Limits of pH 6.0 to 8.0.

Temperature relations: Optimum 37°C. No growth at 22°C. Killed in half an hour at 60°C. or in an hour at 56°C.

Pathogenic.

Strict anaerobe.

Distinctive character: Odor of rancid butter.

Source: Isolated in several cases from suppurations of the urino-genital system.

Habitat: Presumably in bodies of warm-blooded animals.

11. **Neisseria orbiculata** Prévot. (*Diplococcus orbiculus* Tissier, Ann. Inst. Past., *22*, 1908, 204; Prévot, Ann. Sci. Nat., Sér. Bot., *15*, 1933, 109.) From Latin, *orbiculatus*, having the form of an orb or sphere.

Spheres: 1.5 to 2.0 microns, occurring in pairs. Gram-negative.

Gelatin: No growth at 22°C.

Deep agar colonies: After 36 to 48 hours, large, lenticular, very regular, whitish, almost transparent. Gas not produced.

Broth: Turbid. Sediment.

Milk: No coagulation.

Egg white not attacked.

Proteoses attacked without formation of indole.

Acid from glucose. Acid produced feebly from lactose. No acid from sucrose.

Temperature relations: Optimum 37°C. No growth at 22°C. Killed at 60°C.

Non-pathogenic.

Strict anaerobe.

Distinctive characters: Large size; no gas production.

Source: Isolated from feces of young children.

Habitat: Intestinal canal. Not common.

Appendix I: Additional species have been placed in this genus as given below. Some are undoubtedly identical with previously described species, while some may belong in other genera.

Diplococcus crassus von Lingelsheim. (*Diplococcus intracellularis* Jaeger, Ztsch. f. Hyg., *19*, 1893, 353; *Tetracoccus intracellularis*, *ibid.*, 318; von Lingelsheim, Ztschr. f. Hyg., *59*, 1908, 467; *Micrococcus crassus* Lehmann and Neumann, Bakt. Diag., 7 Aufl., *2*, 1927, 259.) Commonly found in nasopharyngeal secretions, also in the cerebrospinal fluid of suspected cases of meningitis. Also known as Jaeger's coccus or as Jaegersher Modifikation der Meningococcus.

Diplococcus mucosus von Lingelsheim. (von Lingelsheim, Klin. Jahrb., *15*, 1906, 373, and Ztschr. f. Hyg., *59*, 1908, 457; *Neisseria mucosa* Murray, in Manual, 5th ed., 1939, 283; not *Streptococcus mucosus* Howard and Perkins, Jour. Med. Res., *6*, (N.S. *1*), 1901, 174; not *Pneumococcus mucosus* Park and Williams, Jour. Exp. Med., *7*, 1905, 411.) From nasal secretions. This Gram-negative coccus is said to show similarity to the meningococcus and to be like the diplococcus found by Weichselbaum and Ghon (Weiner Klin. Wchnschr., No. 24, 1905) in nasal secretions of a healthy person. Clearly it is different from the Gram-positive, mucoid type of pneumococcus which is described by Binaghi (Cent. f. Bakt., I Abt., *22*, 1897, 273), Howard and Perkins (Jour. Med. Res., *6*, 1901, 174), Park and Williams (Jour. Exp. Med., *7*, 1905, 411) and others.

Micrococcus pharyngis cinereus von Lingelsheim. (Klin. Jahrb., *15*, 1906, 373; *Micrococcus cinereus* v. Lingelsheim, Ztschr. f. Hyg., *59*, 1908, 456; *Neisseria cinerea* Murray, in Manual, 5th ed., 1939, 283.) From mucous membrane of nose and throat.

Neisseria arthritica (Costa) Hauduroy et al. (*Micrococcus arthritica* Costa, Comp. rend. Soc. Biol., Paris, *85*, 1920, 933; Hauduroy, Ehringer, Urbain, Guillot and Magrou, Dictionnaire des Bactéries Pathogènes, Paris, 1937, 296.) Isolated from a case of human arthritis.

Neisseria ediglоni (sic) Trevisan. (*Diplococcus scarlatinae sanguinis* Jamieson and Edington, Brit. Med. Jour., *1*, 1887, 1265; Trevisan, I generi e le specie delle Batteriacee, 1889, 32.) From a scarlet fever patient.

Neisseria fulva De Bord. (Jour. Bact., *38*, 1939, 119; Iowa State Coll. Jour. Sci., *16*, 1942, 471.) From conjunctivitis and vaginitis.

Neisseria gibbonsi Hauduroy et al. (Gram-negative coccus, Gibbons, Jour. Inf. Dis., *45*, 1929, 289; Hauduroy et al., Dict. d. Bact. Path., 1937, 300.) Isolated from skin abscesses in rabbits and guinea pigs.

Neisseria gigantea De Bord. (Jour. Bact., *38*, 1939, 119; Iowa State Coll. Jour. Sci., *16*, 1942, 472.) From a normal vagina.

Neisseria luciliarum Brown. (Amer. Mus. Novit., No. 251, 1927, 3.) A motile, Gram-negative diplococcus that probably should be placed in the genus *Micrococcus*. From a dead fly, *Lucilia sericata* killed by *Bacillus lutzae*.

Neisseria pseudocatarrhalis Huntoon. (Jour. Bact., *27*, 1934, 108.) Like *Neisseria catarrhalis*, shows no action on carbohydrates but is culturally more like *Neisseria meningitidis* and forms homogeneous suspensions in a salt solution. From nasopharynx.

Neisseria rebellis Trevisan. (Micrococcus in Trachoma folliculare, Kucharksky, 1887; Trevisan, I generi e le specie delle Batteriacee, Milan, 1889, 32.) From trachoma.

Neisseria venezuelensis Hauduroy et al. (Riguez, Gaceta Med. de Caracas,

June 30, 1935; Pedro del Corral, Rev. de Med. y Cir. de la Clinica Macacay, April, 1935; Hauduroy et al., Dict. d. Bact. Path., 1937, 308.) Found in localized epidemics of cerebrospinal meningitis in Venezuela.

Genus II. **Veillonella** *Prévot.**

(Ann. Sci. Nat., Sér. Bot., *15*, 1933, 118.) Named for A. Veillon, the French bacteriologist, who isolated the type species.

Small, Gram-negative cocci averaging 0.3 micron. Occur in masses, rarely in pairs or short chains. Cells undifferentiated. United by an interstitial substance of ectoplasmic nature. The known species are anaerobic. Good growth on standard culture media. Biochemical activity pronounced. Harmless parasites in mouth and intestine of man and animals.

The type species is *Veillonella parvula* (Veillon and Zuber) Prévot.

Key to the species of genus **Veillonella.**

I. Acid and gas from glucose. Weakly hemolytic.
 1. *Veillonella parvula.*

II. Carbohydrates not attacked. Gas produced from peptone broth. Non-hemolytic.
 2. *Veillonella gazogenes.*

1. **Veillonella parvula** (Veillon and Zuber) Prévot. (*Staphylococcus parvulus* Veillon and Zuber, Arch. méd. Exp., 1898, 542; *Micrococcus parvulus* Bergey et al., Manual, 3rd ed., 1930, 92; Prévot, Ann. Sci. Nat., Sér. Bot., *15*, 1933, 119.) From Latin, *parvulus*, very small.

Description from Prévot (*loc. cit.*).

Very small spheres: 0.2 to 0.4 micron, occurring in masses, occasionally in very short chains. Gram-negative.

Gelatin: No liquefaction.

Semisolid agar (Veillon) colonies: At first punctiform, becoming lenticular, reaching a diameter of 2 mm. Gas bubbles.

Blood agar colonies: Usually surrounded by a clear halo; weakly hemolytic.

Agar slant: Transparent, bluish, minute colonies.

Peptone broth: Turbid with fine sediment.

Glucose broth: Turbid. Faintly fetid odor. Gas produced contains CO_2, H_2 and H_2S.

Broth serum: Very abundant, rapid growth.

Milk: No acid. Not coagulated. Some strains produce gas.

Small amount of indole formed.

Nitrites produced from nitrates.

Acid and gas from glucose. Slight amount of acid from fructose, galactose and sucrose. Some strains feebly attack mannitol, maltose and inulin.

Coagulated protein not attacked.

Ammonia not produced.

Hydrogen sulfide produced.

Optimum pH 6.5 to 8.0.

Temperature relations: Optimum 37°C. Grows feebly at 22°C. Killed in one hour at 55°C.

Strict anaerobe.

Distinctive characters: Fermentation of polypeptids to produce hydrogen, carbon dioxide, hydrogen sulfide and indole; fermentation of sugars; hemolysis of blood; production of nitrites from nitrates.

Source: Isolated by Veillon and Zuber from appendices, buccal cavities and lungs. Of the 13 strains studied by Prévot, 3 were isolated from pulmonary gangrene, one from an appendix, one

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*** Revised by Prof. E. G. D. Murray, McGill University, Montreal, P. Q., Canada, June, 1938. Descriptions reviewed by Dr. Ivan C. Hall, New York City, January, 1944.**

from alveolar pyorrhea, 5 from amniotic fluid, 2 from abscesses and pulmonary congestion and one from the buccal cavity of a normal rabbit. Found in suppurative lesions or pus. It may occasionally be pathogenic and invade the tissues, causing suppurations, alone or in association with other pyogenic organisms.

Habitat: Normally a harmless parasite found in natural cavities of man and animals, especially the mouth and digestive tract.

1a. *Veillonella parvula* var. *minima* Prévot. (*Staphylococcus minimus* Gioelli, Boll. R. Accad. Med. di Genova, 1907; Abst. in Cent. f. Bakt., I Abt., Ref., *42*, 1908–09, 595; *Micrococcus minimus* Bergey et al., Manual, 1st ed., 1923, 69; Prévot, Ann. Sci. Nat., Sér. Bot., *15*, 1933, 125.) From Latin, *minimus*, smallest.

Differs from *Veillonella parvula* only in its slightly smaller size (0.2 to 0.3 micron). Growth only at 37°C. No growth on gelatin. Growth on the wall of the culture tube in fine flakes, not clouding the medium, and no plasmolysis in a 5 per cent salt solution.

Source: Isolated from a periuterine abscess.

1b. *Veillonella parvula* var. *branhamii* Prévot. (Anaerobic micrococcus, Branham, Jour. Inf. Dis., *41*, 1927, 203; *ibid.*, *42*, 1928, 230; *Micrococcus branhamii* Bergey et al., Manual, 3rd ed., 1930, 92; Prévot, Ann. Sci. Nat., Sér. Bot., *15*, 1933, 126.) Named for Dr. Sara E. Branham, of the National Institute of Health, Washington, D. C.

Serologically distinct from *Veillonella parvula*. One strain liquefied gelatin slowly.

Source: Isolated from nasal washings in two cases of influenza.

1c. *Veillonella parvula* var. *thomsonii* Prévot. (Anaerobic diplococcus, Thomson, Jour. Trop. Med. and Hyg., *26*, 1923, 227 and Ann. Pickett-Thomson Res. Lab., *1*, 1924–25, 105 and 164; Prévot, Ann. Sci. Nat., Sér. Bot., *15*, 1933, 126; *Micrococcus thomsoni* Hauduroy et al., Dict. d. Bact. Path., 1937, 283.) Named for Dr. David Thomson of London, England.

Differs but slightly from *Veillonella parvula* in that it requires some accessory factor of growth found in serum or similar body fluids, testicular agar and the like.

Source: Found in the throat in measles and scarlet fever.

2. **Veillonella gazogenes** (Hall and Howitt) Murray. (*Micrococcus gazogenes alcalescens anaerobius* Lewkowicz, Arch. Méd. Exp., *13*, 1901, 633; *Micrococcus gazogenes* Hall and Howitt, Jour. Inf. Dis., *37*, 1925, 112; not *Micrococcus gazogenes* Choukévitch, Ann. Inst. Pasteur, *25*, 1911, 356; *Veillonella alcalescens* Prévot, Ann. Sci. Nat., Sér. Bot., *15*, 1933, 127; *Micrococcus alcalescens* Hauduroy et al., Dict. d. Bact. Path., 1937, 274; Murray, in Manual, 5th ed., 1939, 287.) From Latin, the gas-producing *Veillonella*.

The species name *gazogenes* as given by Hall and Howitt is well established in the literature for this organism. It is valid under the rules when the organism is placed in a new genus (*Veillonella*) in spite of the earlier use of *Micrococcus gazogenes* by Choukévitch for a different organism.

Spheres: 0.3 to 0.7 micron, average 0.4 micron, occurring in irregular masses, rarely in pairs, short chains or singly. Gram-negative.

Gelatin: No liquefaction.

Deep agar colonies: At first punctiform, becoming lenticular. Gas bubbles appear after 16 to 18 hours.

Blood agar plate: Minute colonies. Non-hemolytic. Several strains show greenish colonies.

Peptone broth: Gas produced. Broth becomes slightly alkaline.

Indole not formed.

Milk: Gas, but no acid. No coagulation.

Ammonia and hydrogen produced in small amounts.

Egg-white and coagulated serum not attacked.

Hydrogen sulfide not produced.

Carbohydrates not attacked.

Nitrites not produced from nitrates.

Slowly plasmolysed in 5 per cent NaCl solution.

Optimum pH 6.0 to 8.0. Will grow in broth of pH 5.5.

Temperature relations: Optimum 37°C. Some strains grow at 22°C. Killed at 56°C in one hour, or at 65°C in a half hour, or at 80°C in 10 minutes.

Non-pathogenic (Lewkowicz's strains). Two strains (Prévot) pathogenic for rabbits.

Strict anaerobe.

Distinctive characters: Differs from *Veillonella parvula* in that it does not ferment sugars, does not produce H_2S nor indole, is not hemolytic, does not produce nitrites from nitrates, and does not develop fetid odors.

Source: Isolated (Lewkowicz) from mouth of a healthy infant. Twenty-four strains (Hall and Howitt) from human saliva. Fifteen strains (Prévot) one from alveolar pyorrhea, one from pulmonary gangrene, 5 from tonsils, one from appendix, 2 from measles, 3 from scarlet fever, and 2 from normal guinea pigs and rabbits.

Habitat: Prevalent in saliva of man and animals.

2a. *Veillonella gazogenes* var. *gingivalis* Murray. (Kleiner Micrococcus, Ozaki, Cent. f. Bakt., I Abt., Orig., *62*, 1912, 83; *Micrococcus gingivalis* Bergey et al., Manual, 1st ed., 1923, 69; *Veillonella alcalescens* var. *gingivalis* Prévot, Ann. Sci. Nat., Sér. Bot., *15*, 1933, 133; Murray in Manual, 5th ed., 1939, 288.) From Latin, pertaining to the gums.

Differs from *Veillonella gazogenes* by its ability to grow at 22°C, and by the fact that glucose favors its growth although this carbohydrate is not fermented.

Source: Oral cavity and (Prévot) two strains from the intestine.

2b. *Veillonella gazogenes* var. *minutissima* Murray. (*Micrococcus minutissimus* Oliver and Wherry, Jour. Inf. Dis., *28*, 1921, 342; *Veillonella alcalescens* var. *minutissima* Prévot, Ann. Sci. Nat., Sér. Bot., *15*, 1933, 134; Murray, in Manual, 5th ed., 1939, 288.) From Latin, very tiny.

Differs from *Veillonella gazogenes* only in that the usual carbohydrates favor growth and that the gas formed is not absorbed by sodium hydroxide and is not inflammable.

Non-pathogenic for rabbits, guinea pigs or white mice (Oliver and Wherry).

Source: Two strains isolated from a mixed infection in aphthous ulcers of the gingival and buccal mucosa of a case of postpoliomyelitic paralysis.

2c. *Veillonella gazogenes* var. *syzygios* Murray. (*Syzygiococcus scarlatinae* Herzberg, Cent. f. Bakt., I Abt., Ref., *90*, 1928, 575; *Micrococcus syzygios scarlatinae* Herzberg, Cent. f. Bakt., I Abt., Orig., *111*, 1929, 373; *Micrococcus syzygios* Bergey et al., Manual, 3rd ed., 1930, 92; *Veillonella alcalescens* var. *syzygios* Prévot, Ann. Sci. Nat., Sér. Bot., *15*, 1933, 134; Murray, in Manual, 5th ed., 1939, 288.) From Latin, yoked.

Differs from *Veillonella gazogenes* only by its ability to grow under an atmospheric pressure of 4 cm mercury, with the formation of H_2S in small amounts by some strains, and the production of nitrites from nitrates.

Source: Found by Herzberg in 30 per cent of normal mouths and in 100 per cent of saliva from scarlet fever patients.

FAMILY VII. LACTOBACTERIACEAE ORLA-JENSEN.

(Orla-Jensen, Jour. Bact., *6*, 1921, 271; *Streptobacteriaceae* Bergey, Breed and Murray, Preprint, Manual, 5th ed., 1938, 71.)

Long or short rods, or cocci which divide like rods in one plane only, producing chains, but never tetrads or packets. Non-motile except for certain cultures of streptococci. Gram-positive. Pigment production is rare; a few species form a yellow, orange, red or rusty brown pigment. Surface growth on all media is poor or absent. Some species are strictly anaerobic. Carbohydrates are essential for good development; they are fermented to lactic acid, sometimes with volatile acids, alcohol and CO_2 as by-products (except for the non-fermenting *Diplococcus magnus*). Gelatin is very rarely liquefied. Nitrate is not reduced to nitrite. Found regularly in the mouth and intestinal tract of man and other animals, dairy products, fermenting vegetable juices. A few are highly pathogenic.

Key to the tribes of family **Lactobacteriaceae.**

I. Cocci occurring singly, in pairs and in chains.
Tribe I. *Streptococceae*, p. 305.

II. Rods occurring singly, in pairs and in chains. Individual cells may be very long or even filamentous.
Tribe II. *Lactobacilleae*, p. 349.

TRIBE I. STREPTOCOCCEAE TREVISAN.

(I generi e le specie delle Batteriacee, 1889, 29.)

Cells spherical or elongate, dividing in one plane only, usually occurring in pairs or chains. A few species are strict anaerobes; none grow abundantly on solid media. Carbohydrates and polyalcohols are changed either by homofermentation to lactic acid or by heterofermentation to lactic and acetic acids, alcohol and carbon dioxide. Some pathogenic species grow poorly without blood serum or other enrichment fluids. Catalase negative.

Key to the genera of tribe **Streptococceae.**

I. Parasites, growing poorly on artificial media. Cells usually in pairs, often elongated. Anaerobic species rarely in tetrads or small clumps.
Genus I. *Diplococcus*, p. 305.

II. Parasites and saprophytes. Normally forming short or long chains. Ferment glucose to lactic acid with practically no other acids or CO_2.
Genus II. *Streptococcus*, p. 312.

III. Saprophytes. Form chains of cocci to short rods in plant juices and milk. Ferment glucose with the production of CO_2, lactic acid, acetic acid and ethyl alcohol. Mannitol is formed from fructose.
Genus III. *Leuconostoc*, p. 346.

Genus I. **Diplococcus** *Weichselbaum.**

(Weichselbaum, Wiener med. Jahrb., *82*, 1886, 483; *Hyalococcus* Schroeter, in Cohn, Kryptogamen Flora v. Schlesien, 1886, 152; *Pseudodiplococcus* Bonome, Cent. f. Bakt.,

* Revised by Prof. E. G. D. Murray, McGill University, Montreal, Canada, September, 1938; anaerobic section adapted from papers by Dr. A. R. Prévot, Institut Pasteur, Paris, France, 1938; further revision by Lt. Col. Elliott S. Robinson, M.C., Washington, D. C., January, 1944.

2, 1888, 321; ? *Pneumococcus* Schmidlechner, Ztschr. f. Geburtshilfe u. Gynäkol., *56*, 1905, 291; not *Pneumococcus* Arloing, Compt. rend. Acad. Sci., Paris, *109*, 1889, 430; *Mogallia* Enderlein, Sitzb. Gesell. Naturf. Freunde, Berlin, 1917, 309.) From Greek *diploos*, double; *kokkos*, a grain or berry; M. L., a sphere.

Cells usually in pairs, sometimes in chains or more rarely in tetrads or small clumps. Young cells Gram-positive. Parasites sometimes growing poorly or not at all on artificial media. Fermentative powers usually high, most strains forming acid from glucose, lactose, sucrose and inulin. The aerobic species are bile soluble while the anaerobic species are not bile soluble.

The relationships of the strictly anaerobic diplococci placed in this genus by Prévot (Ann. Sci. Nat., Sér. Bot., *15*, 1933, 140) to pneumococci are not yet entirely clear. The anaerobic species are included here in the hope that this arrangement will stimulate research.

The type species is *Diplococcus pneumoniae* Weichselbaum.

Key to the species of genus **Diplococcus.**

I. Aerobic, facultative. Bile soluble.
    1. *Diplococcus pneumoniae.*
II. Strictly anaerobic. Not bile soluble.
  A. Greater than 1 micron in diameter.
    1. Carbohydrates not attacked.
      2. *Diplococcus magnus.*
  B. Not greater than 1 micron in diameter.
    1. Acid from glucose and lactose.
      a. Capsulated. Pathogenic.
        3. *Diplococcus paleopneumoniae.*
      aa. Not capsulated. Non-pathogenic.
        4. *Diplococcus plagarum-belli.*
    2. Acid from glucose, not from lactose.
      a. Grows on ordinary culture media. Non-pathogenic.
        5. *Diplococcus constellatus.*
      aa. No growth on ordinary culture media. Pathogenic.
        6. *Diplococcus morbillorum.*

1. **Diplococcus pneumoniae** Weichselbaum. (Microbe septicémique du salive, Pasteur, Chamberland and Roux, Compt. rend. Acad. Sci., Paris, *92*, 1881, 159; Micrococcus of rabbit septicemia, Sternberg, National Board of Health Bull., Washington, *2*, 1881, 781; Coccus lancéolé, Talamon, Communication à la Société anatom. de Paris, *58*, 1883, 475; *Micrococcus pyogenes tenuis* Rosenbach, Mikroorganismen bei den Wundinfektionskrankheiten des Menschen, 1884, 30 (see Neumann, Cent. f. Bakt., 7, 1890, 177); *Micrococcus pasteuri* Sternberg, Trans. Pathol. Soc. of Philadelphia, *12*, 1885, 162 (not *Micrococcus pasteuri* Trevisan, I generi e le specie delle Batteriacee, 1889, 34); Weichselbaum, Wiener med. Jahrb., *82*, 1886, 485; Pneumoniemikrococcus or Pneumococcus, Fränkel, Ztschr. f. klin. Medizin, *10*, 1886, 402; *Bacillus septicus sputigenus* Flügge, Die Mikroorganismen, 2 Aufl., 1886, 262; *Bacillus salivarius septicus* Biondi, Ztschr. f. Hyg., *2*, 1887, 195; *Diplococcus lanceolatus* sive *capsulatus* Foà and Bordoni-Uffreduzzi, Archivio per le Sci. Med., *11*, 1887, 387; *Streptococcus lanceolatus pasteuri* Gamaléia, Ann. Inst. Past., *2*, 1888, 442; *Streptococcus lanceolatus* Gamaléia, *ibid.*, 443; *Klebsiella salivaris* Trevisan, I generi e le specie

delle Batteriacee, 1889, 26; *Micrococcus rosenbachii* Trevisan, *ibid.*, 33; *Micrococcus pyogenes-tenuis* De Toni and Trevisan, in Saccardo, Sylloge Fungorum, *8*, 1889, 1031; *Micrococcus pneumoniae crouposae* Sternberg, Cent. f. Bakt., *12*, 1892, 53; *Diplococcus lanceolatus capsulatus* Kruse and Pansini, Ztschr. f. Hyg., *11*, 1892, 335; *Diplococcus lanceolatus* incorrectly ascribed to Fränkel by Binaghi, Cent. f. Bakt., I Abt., *22*, 1897, 278; *Micrococcus tenuis* Migula, Syst. d. Bakt., *2*, 1900, 193; *Bacterium pneumoniae* Migula, *ibid.*, 347; *Bacterium salivarium* Migula, *ibid.*, 379; *Streptococcus pneumoniae* Chester, Man. Determ. Bact., 1901, 63; *Micrococcus lanceolatus* Longcope, Jour. Med. Res., *7* (N.S. *2*), 1902, 220; *Pneumococcus lanceolatus* Schmidlechner, Ztschr. f. Geburtshilfe u. Gynäkologie, *56*, 1905, 291; *Pneumococcus pneumoniae* Fried, Jour. Exp. Med., *57*, 1933, 111.) From Greek *pneumonia*, inflammation of the lungs.

Monas pulmonale Klebs (Arch. f. exper. Path. u. Pharmakol., *4*, 1875, 472) is inadequately described by Klebs and ought not to be regarded as identical with Weichselbaum's organism.

Common name: Pneumococcus.

The organisms occur as oval or spherical forms typically in pairs, occasionally singly or in short chains, 0.5 to 1.25 microns. The distal ends of each pair of organisms tend to be pointed or lancet-shaped. Encapsulated. Non-motile. Young cells, Gram-positive.

Gelatin stab: Filiform or beaded growth. No liquefaction.

Infusion agar colonies: Small, transparent, grayish, with entire margin. Elevation high convex, glistening, mucoid to watery.

On blood agar, the colonies are elevated at the center with concentric elevations and depressions. Hemolysis usually slight but often marked in anaerobic culture; methemaglobin formation with green zone around colony.

Beef heart infusion broth: Uniform turbidity with variable amount of sediment.

Addition of glucose, serum, whole blood or ascitic fluid enhances growth.

Meat extract media: Growth irregular, usually poor if any.

Inulin serum water: Usually acid with coagulation.

Litmus milk: Usually acid with coagulation.

Potato: No growth.

Whole bile or 10 per cent solutions of sodium taurocholate or sodium glycocholate added to actively growing broth cultures will dissolve the organisms. It is customary to use from 0.1 to 0.5 ml of bile for each 0.5 ml of culture.

Aerobic, facultative.

Optimum temperature 37°C. Usually no growth at 18° to 22°C.

Optimum initial pH 7.8.

Source: Sputum, blood and exudates in pneumonia; cerebrospinal fluid in meningitis; mastoiditis; otitis media; peritonitis; empyema; pericarditis; endocarditis; arthritis; saliva and secretions of respiratory tract in normal persons. Commonest cause of lobar pneumonia.

Habitat: The respiratory tract of man and animals.

At present, thirty-one types of *Diplococcus pneumoniae* are recognized on the basis of serological reactions, chiefly the Neufeld "Quellung" phenomenon as induced by type-specific immune rabbit serums. Following the description of Pneumococcus 1 by Neufeld and Händel (Arb. a. d. k. Gesundheitsamte, *34*, 1910, 293), Dochez and Gillespie (Jour. Amer. Med. Assoc., *61*, 1913, 727) divided the species into Types 1, 2, 3 and a heterogenous group 4; Cooper, Edwards and Rosenstein (Jour. Exp. Med., *49*, 1929, 461) separated Types 4 to 13 from the strains previously designated as group 4, and later Cooper, Rosenstein, Walter and Peizer (Jour. Exp. Med., *55*, 1932, 531)

continued the classification to Type 32. Due to marked cross-reactions, it was subsequently decided that Type 6 was identical with Type 26, and that Types 15 and 30 were identical. This resulted in the deletion of the Cooper Types 26 and 30, thus leaving thirty of the original thirty-two types. Type 33 (Wilder) has been described by Walter, Blount, Beattie and Cotler (Jour. Inf. Dis., *66*, 1940, 181) as a distinct type; sufficient recognition has been accorded to justify the acceptance of this type, thereby making a total of thirty-one types of the species. In a still more recent publication, Walter, Guevin, Beattie, Cotler and Bucca (Jour. Immunol., *41*, 1941, 279) recommend the addition of nine new types and eight subtypes. These, together with new strains reported by Kauffmann, March and Schmith (Jour. Immunol., *39*, 1940, 397), if eventually recognized, would make a total of fifty-five types. Eddy still more recently, taking into account all known types, raises the number of recognized types to seventy five (U. S. Public Health Repts., *59*, 1944, 449–468).

NOTE 1. *Streptococcus mucosus* Howard and Perkins. (Howard and Perkins, Jour. Med. Res., *6* (N.S. *1*), 1901, 174; *Diplococcus capsulatus* incorrectly attributed to Fränkel by Binaghi, Cent. f. Bakt., I Abt., *22*, 1897, 273; *Streptococcus mucosus* Schottmüller, Münch. med. Wchnschr., *50*, 1903, 909; *Streptococcus lanceolatus* var. *mucosus* Park and Williams, *Diplococcus lanceolatus* var. *mucosus* Park and Williams, *Diplococcus mucosus* Park and Williams, *Pneumococcus mucosus* Park and Williams, Jour. Exp. Med., *7*, 1905, 411; *Streptococcus mucosus capsulatus* Buerger, Cent. f. Bakt., I Abt., *41*, 1906, 314.) This organism is no longer recognized as a separate species. Dochez and Gillespie (Jour. Amer. Med. Assoc., *61*, 1913, 727), Wirth (Cent. f. Bakt., I Abt., Orig., *102*, 1928, 40) and others have established the identity of strains of this group as *Diplococcus pneumoniae*, Type 3.

Buerger (Cent. f. Bakt., I Abt., Orig., *41*, 1906, 314) lists the following capsulated closely related streptococci: *Streptococcus involutus* Kurth, Arb. a. d. k. Gesundheitsamte, *8*, 1893, 449 (*Diplococcus involutus* Winslow and Winslow, The Systematic Relationships of the Coccaceae, New York, 1908, 131); *Streptococcus aggregatus* Seitz, Cent. f. Bakt., I Abt., *20*, 1896, 854; *Streptococcus capsulatus* Binaghi, Cent. f. Bakt., I Abt., *22*, 1897, 273; Streptocoque auréole, Le Roy des Barres and Weinberg, Arch. de Méd. expér. et d'anat. pathol., *2*, 1899, 399; *Leuconostoc hominis* Hlava, Cent. f. Bakt., I Abt., Orig., *32*, 1902, 263.

NOTE 2. Pneumococci, regardless of serological type, manifest three chief culture phases (or stages): Mucoid, Smooth, and Rough. The Mucoid (M) form corresponds to that previously designated as Smooth (S) and represents the typical phase of the species; Smooth (S) supercedes the earlier term Rough (R); and the present Rough (R) form is a relatively newly-described variant. The most frequently observed dissociative trend is M → S → R. Serological types are recognizable only in the Mucoid form due to the presence of type-specific polysaccharides in the capsular material; both Smooth and Rough forms are devoid of capsular material, but possess species-specific antigens common to all members of the species. Smooth and Rough forms are non-pathogenic, possess distinctive growth characteristics, and require special technic for accurate observations. The cultural characteristics given are those of the mucoid and smooth phases only, e. g., see growth in broth.

*† **Diplococcus magnus** Prévot. (*Diplococcus magnus anaerobius* Tissier and

* Anaerobic section reviewed by Dr. Ivan C. Hall, New York, N. Y.

† These anaerobic diplococci and streptococci, many of which are putrefactive

Martelly, Ann. Inst. Past., *16*, 1902, 885; Prévot, Ann. Sci. Nat., Sér. Bot., *15*, 1933, 140.) From Latin *magnus*, large.

Large spheres: 1.5 to 1.8 microns, usually in pairs, sometimes occurring singly, in small clumps or very short chains. Gram-positive.

Gelatin: Growth slow, scanty. No liquefaction.

Deep agar colonies: After 24 hours at 37°C, lenticular, whitish, granular; margin finely cut. No gas produced.

Broth: Turbid, clearing in 4 or 5 days resulting in a viscous mass similar to the zoogloea which *Clostridium bifermentans* forms.

Peptone water: Slight turbidity. Indole not formed.

Milk: Unchanged.

Fibrin not digested.

Sterilized urine: Turbid in 3 to 4 days. The urea is attacked forming $(NH_4)_2CO_3$.

Proteoses: Digested and disintegrated forming $(NH_4)_2CO_3$ with the liberation of NH_3.

Carbohydrates not attacked.

Optimum pH 7.0. Limits of pH 5.5 to 8.5.

Temperature relations: Optimum 37°C. Grows from 18° to 37°C. Killed in five minutes on boiling or in half an hour at 60°C.

Non-pathogenic.

Strict anaerobe.

Distinctive characters: Large size; very marked alkalinizing power.

Source: Isolated by Tissier and Martelly (*loc. cit.*) from putrefying butcher's meat. Isolated by Prévot (*loc. cit.*) from a case of acute appendicitis.

Habitat: Human digestive tract. Very common on butcher's meat in the process of putrefaction. Probably occurs in household dust.

3. **Diplococcus paleopneumoniae** Prévot. (An anaerobic pseudopneumococcus, Rist, Thèse de Paris, 1898; Der Fränkelsche Diplococcus, Bolognesi, Cent. f. Bakt., I Abt., Orig., *43*, 1907, 113; Prévot, Ann. Sci. Nat., Sér. Bot., *15*, 1933, 143.) From Greek *paleus*, old and *pneumonia*, inflammation of the lungs.

Spheres: About 0.7 to 1.0 micron, occurring in pairs, rarely occurring singly or in very short chains. Capsulated. Gram-positive.

Gelatin: No liquefaction.

Deep agar colonies: Probably lenticular.

Agar slant colonies: Round, raised, transparent, dew-drop.

Broth: Opalescent turbidity which settles as a rather abundant, powdery, flocculent precipitate. No gas produced.

Glucose or lactose broth: Rapid, abundant growth.

Peptone water (2 per cent): Very slow development. After 4 or 5 days at 37°C growth very poor.

Milk: Good growth. Partial coagulation.

Blood agar: Very rapid, abundant growth.

Acid from glucose and lactose.

Temperature relations: Optimum 37°C. No growth at 20°C nor at 42°C. Killed at 55°C.

Pathogenic.

Strict anaerobe.

Distinctive characters: Resembles

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and gas-forming, seem to us so different from the fermentative microaerophilic diplococci, streptococci, leuconostocs and lactobacilli that we beleive they should be placed in genera and in a family separate from *Lactobacteriaceae*. Prévot in a discussion (Ann. Inst. Past., *67*, 1941, 87) that has just reached us (Oct., 1945) recognizes this difference in physiology. He would solve the difficulty by returning the fermentative diplococci and streptococci to the family *Coccaceae* because of resemblances in morphology which do not seem to us to be fundamental—The editors.

Diplococcus pneumoniae but is a strict anaerobe; highly pathogenic.

Source: Isolated by Rist (*loc. cit.*) from an osseous abscess; by Bolognesi (*loc. cit.*) from lesions of pleuropneumonia.

Habitat: Buccal-pharyngeal cavity of man and rodents.

4. **Diplococcus plagarum-belli** Prévot. (Diplococcus from septic wounds, Adamson, Jour. Path. and Bact., *22*, 1919, 393; Prévot, Ann. Sci. Nat., Sér. Bot., *15*, 1933, 157.) From Latin *plaga*, wound; *bellum*, war.

Spheres: 0.6 to 1.0 micron, occurring in pairs of unequal size or in short chains. Gram-positive.

Gelatin: No liquefaction.

Deep agar colonies: Appear after 24 to 48 hours, gradually increasing in size to 2 mm in diameter; lenticular, regular, almost transparent. Gas not produced, even in glucose agar.

Broth: Growth precipitates in 5 or 6 days. No gas produced.

Indole not formed.

Milk: Strongly acidified and coagulated in 2 to 3 days.

Serum not digested.

Acid but not gas from glucose, maltose, lactose and sucrose. No acid from mannitol.

Temperature relations: Optimum 37°C. Not always killed in half an hour at 80°C.

Non-pathogenic.

Strict anaerobe.

Source: Sixteen strains isolated from fifty-one cases of septic war wounds.

Habitat: Common in septic wounds.

5. **Diplococcus constellatus** Prévot. (Compt. rend. Soc. Biol. Paris, *91*, 1924, 426.) From Latin *constellatus*, studded with stars.

Description in part from Prévot, Ann. Sci. Nat., Sér. Bot., *15*, 1933, 158.

Spheres: 0.5 to 0.6 micron, occurring in pairs and tetrads, rarely in very short chains, never in clusters. Gram-positive.

Gelatin: Good growth. No liquefaction.

Deep agar colonies: At first very small, lenticular, biconvex, thick, opaque, yellowish, 0.5 to 1.5 mm in diameter. Each colony surrounded by many small satellite colonies visible microscopically.

Broth: Growth slow, poor. After 48 hours a slight homogenous turbidity which quickly clears, leaving a slight powdery sediment. Neither gas nor odor produced.

Glucose broth: Growth rapid, abundant.

Proteins not attacked.

Blood broth: Good growth. No hemolysis.

Milk: Poor growth. No change.

Peptone water: Good growth. Not acidified. Indole not formed.

Neutral red broth unchanged.

Acid but not gas from glucose, arabinose. Slightly acid from glycerol. No acid from lactose, inulin, mannitol or dulcitol.

Optimum pH 6.0 to 8.0.

Optimum temperature 37°C. Feeble growth at 22°C. Not thermo-resistant.

Strict anaerobe.

Distinctive character: The microscopic appearance of agar colonies each of which is surrounded by a constellation of satellites.

Source: Isolated from a case of chronic, cryptic tonsillitis. Later isolated from pus in acute appendicitis.

Habitat: Digestive tract, especially the lymphoid tissues, as tonsils and appendix.

6. **Diplococcus morbillorum** Prévot. (Diplococci from cases of measles, Tunnicliff, Jour. Amer. Med. Assoc., *68*, 1917, 1028; *Diplococcus rubeolae* Tunnicliff, Jour. Inf. Dis., *52*, 1933, 39; Prévot, Ann. Sci. Nat., Sér. Bot., *15*, 1933, 148; original name withdrawn by Tunnicliff,

Jour. Inf. Dis., *58*, 1936, 1.) From Latin *morbus*, disease; M. L. *morbilli*, measles.

Spheres: 0.6 to 0.8 micron, occurring in short chains, rarely in small masses. Gram-positive.

This organism does not develop on ordinary culture media. The addition of fresh serum or ascitic fluid is necessary.

Gelatin: No liquefaction.

Serum agar colonies: Very small, punctiform, appearing after 5 to 22 days. No gas produced.

Glucose agar containing ascitic fluid and blood: Colonies are slightly larger and appear more rapidly; greenish.

Blood agar colonies: Surrounded by a greenish halo. May be large and moist. Gas not produced.

Broth: Very poor growth.

Hemolysed blood broth: Growth flocculent, leaving the liquid clear.

Milk: Unchanged by most strains. Acidified and coagulated by four strains.

Indole not formed.

Bile: Not soluble in bile.

Acid from glucose, sucrose and maltose.

Temperature relations: Optimum 37°C. Killed in 45 minutes at 57°C. Withstands −2°C for two weeks.

Strict anaerobe. Most strains become microaerophilic with transfers.

Distinctive characters: Greenish colonies on blood media; poor growth on ordinary media.

Source: Isolated from the throat and blood in measles.

Habitat: Nose, throat, eyes, ears, mucous secretions and blood from cases of measles.

Genus II. **Streptococcus** *Rosenbach.**

(Rosenbach, Mikroorganismen bei Wundinfektionskrankheiten des Menschen, 1884, 22; *Arthrostreptokokkus* Hueppe, Wiesbaden, 1886, 144; *Sphaerococcus* Marpmann, Ergänzungshefte z. Cent. f. allg. Gesundheitspflege, *2*, 1889, 121; *Perroncitoa, Babesia, Schuetzia* Trevisan, I generi e le specie delle Batteriacee, 1889, 29; *Lactococcus* Beijerinck, Arch. neérl. d. sci. exactes, Sér. 2, *7*, 1901, 213; *Hypnococcus* Bettencourt et al., Cent. f. Bakt., I Abt., Orig., *35*, 1904, 55; *Myxococcus* Gonnermann, Oester. u. Ungar. Ztschr. f. Zuckerind. u. Landwirtsch., *36*, 1907, 883; not *Myxococcus* Thaxter, Bot. Gaz., *17*, 1892, 404; *Melococcus* Amiradzibi, Med. Zurn., *4*, 1907, 309; *Diplostreptococcus* v. Lingelsheim, in Kolle and Wassermann, Handb. d. path. Mikroorg., 2 Aufl., *4*, 1912, 494; ? *Brachybacterium* Troili-Petersson, Cent. f. Bakt., II Abt., *11*, 1903, 138; *Pseudostreptus* Enderlein, Sitzb. Gesell. Naturf. Freunde, Berlin, 1917, 309; *Planostreptococcus* Meyer, Die Zelle der Bakterien, Jena, 1912, 4; *Streptus* Enderlein, Sitzber. Gesell. Naturf. Freunde, Berlin, 1930, 104; *Peptostreptococcus* Kluyver and Van Niel, Cent. f. Bakt., II Abt., *94*, 1936, 391.) From Greek *streptus*, flexible or pliant; Greek *kokkos*, a grain or berry; M. L., a sphere.

Cells spherical or ovoid, rarely elongated into rods, occurring in pairs, or short or long chains, never in packets or zoogloeal masses. Capsules are not regularly formed, but become conspicuous with some species under certain conditions. Gram-positive, some species decolorizing readily. A few cultures produce a rusty red growth in deep agar stab, or a yellow or orange pigment in starch broth. Growth on artificial media is slight. Agar colonies are small. Surface colonies are translucent. Colonies may be effuse, convex or mucoid. Some species are aided by the addition of native proteins. Mostly facultative anaerobes, with little surface growth in stab cultures. A few are strict anaerobes. Some of the latter attack proteins with production of gas and foul odors. Carbohydrate fermentation by all others is homofermentative, with dextrorotatory lactic acid as the dominant product, while volatile acids, other volatile products and CO_2 are either absent or produced in very small amounts. Inulin is rarely attacked. Nitrate is not reduced to nitrite. Not soluble in bile. Common wherever organic matter containing sugars is accumulated. Regularly in the mouth and intestine of man and other animals, dairy products, fermenting plant juices. Some species are highly pathogenic.

The type species is *Streptococcus pyogenes* Rosenbach.

NOTE: The classification of streptococci is beset with many difficulties and it seems advisable for the present to accept only such described species about which there is reasonable agreement. With present knowledge, many species which have been separated can justifiably be considered as identical with older species and have been treated as such here. The descriptions of certain other species do not permit their exact identification now and they have been classed as invalid names with no present significance. It is admitted there are grounds for belief that more than one species may be included in certain of the species described here, but the onus of proof lies with the investigators interested in them. It is hoped that the simplification introduced will prove useful as a starting point for the more exact differentiation and description of the species of *Streptococcus*. The general arrangement used is in

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* Revised by Prof. E. G. D. Murray, McGill University, Montreal, Canada, in consultation with Prof. G. J. Hucker, New York State Experiment Station, Geneva, New York and Prof. J. M. Sherman, Cornell University, Ithaca, New York, June, 1938; further revision by Prof. J. M. Sherman, February, 1944.

harmony with the suggestions made by Hucker (Proc. 2nd Internat. Cong. for Microbiology, London, 1936, 127) and Sherman (Bact. Reviews, *1*, 1937, 3).

Serological reactions are included as far as possible in the descriptions but the true significance of these methods is not known and on that account they are not stressed in the primary classification.

Throughout the history of this genus motile streptococci have been reported occasionally (e.g., *Streptococcus herbarum* Schieblich, Cent. f. Bakt., I Abt., Orig., *124*, 1932, 269; Koblmüller, Cent. f. Bakt., I Abt., Orig., *133*, 1934, 310; Stölting, Über die Streptokokken des normal reifenden Tilsiter Käses. Inaug. Diss., Kiel, 1935, 51; Pownall, Brit. Jour. Exp. Path., *16*, 1935, 155) but it is not known whether these constitute definite species or whether (Levenson, Ann. Inst. Past., *60*, 1938, 99) motile individuals occasionally appear in ordinarily non-motile species.

The anaerobic streptococci have not been sufficiently studied to be sure whether they should be included in the genus *Streptococcus* or given separate generic rank. Their metabolic processes seem reason for the latter view. The descriptions given are taken from Prévot (Ann. Sci. Nat., Sér. Bot., *15*, 1933, 23).

The material is arranged accordingly in three categories: A key and complete descriptions have been prepared for clearly defined species, species of uncertain taxonomic relationships have been placed in Appendix I with their necessarily incomplete descriptions, while even less valid and unidentifiable species are merely listed in Appendix II.

Key to the species of genus Streptococcus.

I. Facultative anaerobic species.
  A. *Pyogenic group.* No growth at 10°C. No growth at 45° C. Generally beta hemolytic. Generally do not curdle litmus milk and reduce litmus slowly if at all. Mannitol and glycerol generally not fermented. Not tolerant of 0.1 per cent methylene blue, 6.5 per cent NaCl and pH 9.6. Produce ammonia from peptone.
    1. Sodium hippurate not hydrolyzed.
      a. Lactose fermented.
        b. Sorbitol not fermented but trehalose fermented. Lancefield Group A.
          1. *Streptococcus pyogenes.*
        bb. Sorbitol fermented and trehalose not fermented. Lancefield Group C.
          2. *Streptococcus zooepidemicus.*
      aa. Lactose may or may not be fermented. Lancefield Group C.
        b. Trehalose not fermented.
          3. *Streptococcus equi.*
        bb. Trehalose fermented.
          4. *Streptococcus equisimilis.*
    2. Sodium hippurate hydrolyzed. Lancefield Group B.
          5. *Streptococcus agalactiae.*
  B. *Viridans group.* No growth at 10°C. Growth at 45°C (few exceptions in *Streptococcus mitis*). Reduce litmus after curdling litmus milk; sorbitol and glycerol generally not fermented; mannitol rarely. Not tolerant of 0.1 per cent methylene blue, 6.5 per cent NaCl or pH 9.6. Not beta

hemolytic (though they may be under anaerobic conditions) but show varying degrees of greening of blood. Do not produce ammonia from peptone (few exceptions in *Streptococcus mitis*).

1. Lactose is fermented.
   a. Do not grow at 50°C. Greening or indifferent in blood agar. Raffinose, inulin, salicin and dextrin generally fermented. Esculin generally attacked. Growth with 2 per cent NaCl.
      b. Do not survive 60°C for 30 minutes. Starch not hydrolyzed. Not tolerant of bile.
         c. Mucoid colonies produced on sucrose and raffinose media.
            6. *Streptococcus salivarius*.
         cc. Colonies not mucoid on sucrose or raffinose media. Inulin not fermented.
            7. *Streptococcus mitis*.
      bb. Survives 60°C for 30 minutes. Starch is hydrolyzed except by variety *inulinaceus*. Tolerant of bile.
            8. *Streptococcus bovis* (and varieties).
   aa. Grows at 50°C. No action on blood. Esculin not attacked. Raffinose, inulin, salicin and dextrin not fermented. No growth in 2 per cent NaCl.
            9. *Streptococcus thermophilus*.
2. Lactose not fermented. Tolerant of bile.
            10. *Streptococcus equinus*.

C. *Lactic group*. Growth at 10°C. No growth at 45°C. Reduce litmus prior to curdling of litmus milk. Sorbitol and glycerol not fermented. Not beta hemolytic. Tolerate 0.1 per cent methylene blue, but do not tolerate 6.5 per cent NaCl or pH 9.6.
   1. Maltose and dextrin fermented. Ammonia produced from peptone. Growth at 40°C. Group N of Shattock and Mattick.
            11. *Streptococcus lactis*.
   2. Maltose and usually dextrin not fermented. Ammonia not produced from peptone. No growth at 40°C.
            12. *Streptococcus cremoris*.

D. *Enterococcus group*. Growth at 10°C. Growth at 45°C. Usually reduce litmus prior to curdling litmus milk. Sorbitol, glycerol and mannitol generally fermented. May or may not be beta hemolytic. Tolerate 0.1 per cent methylene blue, 6.5 per cent NaCl and pH 9.6. Ammonia produced from peptone. Lancefield Group D.
   1. Not beta hemolytic.
      a. Gelatin not liquefied.
            13. *Streptococcus faecalis*.
      aa. Gelatin liquefied.
            14. *Streptococcus liquefaciens*.
   2. Beta hemolytic.
      a. Mannitol and sorbitol fermented.
            15. *Streptococcus zymogenes*.
      aa. Mannitol and sorbitol not fermented.
            16. *Streptococcus durans*.

II. Anaerobic species.
   A. Strict anaerobes.
      1. Gas and fetid odor produced.
         a. No general turbidity in broth.

b. Acid from maltose.

17. *Streptococcus anaerobius.*

bb. No acid from maltose.

18. *Streptococcus foetidus.*

aa. Turbidity in broth.

b. No gas in Veillon's semisolid agar. No gas in peptone water.

19. *Streptococcus putridus.*

bb. Abundant gas in semisolid agar. Gas in peptone water.

20. *Streptococcus lanceolatus.*

2. No gas and no fetid odor produced.

a. Milk not coagulated.

21. *Streptococcus micros.*

aa. Milk coagulated.

b. Viscous sediment in broth. Semisolid agar colonies blacken with age.

22. *Streptococcus parvulus.*

bb. No viscous sediment in broth. Semisolid agar colonies do not blacken with age.

23. *Streptococcus intermedius*

B. Microaerophilic.

1. Strictly anaerobic on isolation, later microaerophilic.

24. *Streptococcus evolutus.*

1. **Streptococcus pyogenes** Rosenbach. (Fehleisen, Ueber Erysipel, Deut. Zeit. f. Chir., *16*, 1882, 391; Erysipelkokken, Fehleisen, Die Aetiologie des Erysipels, Berlin, 1883; Rosenbach, Mikroorganismen bei Wundinfektionskrankheiten des Menschens, 1884, 22; *Streptococcus erysipelatos* (sic) Rosenbach, *ibid.*, 22; *Micrococcus erysipelatis* Zopf, Die Spaltpilze, 2 Aufl., 1884, 86; *Streptococcus erysipelatis* Zopf, Die Spaltpilze, 3 Aufl., 1885, 51; *Streptococcus erysipelatosus* Klebs, Die Allg. Path., Jena, 1887, 318; *Micrococcus scarlatinae* and *Streptococcus scarlatinae* Klein, Report of the Medical Officer of the Local Government Board for 1885–1886, No. 8, 1887, 85; *Streptococcus conglomeratus* Kurth, Arb. d. k. Gesundheitsamte, 7, 1891, 389; *Streptococcus longus* von Lingelsheim, Ztschr. f. Hyg., *10*, 1891, 331 and *12*, 1891, 3C8; *Streptococcus puerperalis* Arloing, Septicémie puerperale, Paris, 1892 (Jordan, Brit. Med. Jour, 1912, 1); *Staphylococcus erysipelatos* Hesse, Ztschr. f. Hyg., *34*, 1900, 347; *Streptococcus longus pathogenes* seu *erysipelatos* Schottmüller, Münch. med. Wchnschr., *50*, 1903, 909; *Streptococcus longus hemolyticus* Sachs, Ztschr. f. Hyg., *63*, 1909, 466; *Streptococcus longissimus* Thalmann, Cent. f. Bakt., I Abt., Orig., *56*, 1910, 248; *Streptococcus hemolyticus* Rolly, Cent. f. Bakt., I Abt., Orig., *61*, 1911, 87; *Streptococcus epidemicus* Davis, Jour. Am. Med. Assoc., *58*, 1912, 1852; Jour. Inf. Dis., *15*, 1914, 378; *ibid.*, *19*, 1916, 236; *Streptococcus hemolysans* Blake, Jour. Med. Res., *36* (N.S. *31*), 1917, 116; *Streptococcus pyogenes haemolyticus* Weisenbach, Compt. rend. Soc. Biol. Paris, *81*, 1918, 819; *Streptus scarlatinae* Enderlein, Sitzber. Geseil. Naturf. Freunde Berlin, 1930, 104; *Streptococcus pyogenes* var. *scarlatinae* Hauduroy et al., Dict. d. Bact. Path., Paris, 1937, 520.) From Greek *pyon*, pus; *-genes*, producing.

Spherical or ovoid cells: 0.6 to 1 micron in diameter in cultures; usually spherical in blood and inflammatory exudates; occurring in chains or pairs. Capsules are variable, sometimes well developed and can be induced. Gram-positive.

Gelatin stab: Growth slight; minute opaque colonies, little surface growth. No liquefaction.

Nutrient agar: Small colonies, translucent, convex, entire, slightly granular; colonies are variable; confluent growth a thin transparent film; tendency for

colonies to remain discrete. Growth increased by addition of blood or native proteins. Pairs or short chains in surface growth and longer chains in condensation fluid of slants.

Broth: Flocculent sediment of tangled, chains, supernatant broth often clear except in very young cultures. No pellicle.

Potato: Very slight or no visible growth.

Litmus milk: Acid, seldom curdled, and litmus reduced slowly or not at all.

Acid from glucose, maltose, lactose, sucrose, salicin and trehalose. No acid from inulin, raffinose, arabinose, glycerol, mannitol, sorbitol or dulcitol.

No hydrolysis of sodium hippurate, starch or esculin.

Ammonia is produced from peptone.

Temperature relations: Optimum temperature around 37°C. No growth at 10°C or 45°C. Does not survive 60°C for 30 minutes.

Chemical tolerance: Tolerates 2 per cent NaCl but not 4 per cent and 6.5 per cent. Final pH in glucose broth 4.8 to 6.0; no growth at pH 9.6. Methylene blue 0.01 per cent and 0.1 per cent not tolerated and not reduced. Inhibited by bile but not soluble.

Action on blood: Superficial and deep colonies cause hemolysis in blood agar, usually with a wide zone surrounding the colony, which may have a well-defined margin circumscribed by a zone of concentrated hemoglobin; the margin of the zone is ill-defined with some strains. Conditions defined by Brown (Rockefeller Inst. Med. Res., Monograph 9, 1919, 14) known as beta hemolysis. Soluble antigenic hemolysin of more than one kind produced in fluid cultures; influenced by constitution of medium and presence of serum; one is oxygen-sensitive and another is oxygen-stable. Special precautions necessary for its demonstration (F. Smith, Jour. Bact., *34*, 1937, 585, 603).

Toxin: An erythrogenic toxin is produced; commonly associated with scarlet fever. Relatively thermostable.

Fibrinolysin: Dissolves human fibrin but not fibrin of rabbit or ox blood. Markedly thermostable.

Serology: Constitutes Group A of Lancefield (C substance; polysaccharide) (Jour. Exp. Med., *57*, 1933, 571). Types within the species are distinguishable (M substance; protein); 23 identified by Griffith (Jour. Hyg., *34*, 1934, 542). Antigen common to the group (P substance; nucleo-protein) also present in other Gram-positive cocci.

Facultative anaerobe. Occasionally in primary culture from lesions, pus, etc. grows only in anaerobic culture.

Source: Human mouth, throat and respiratory tract; inflammatory exudates, blood stream and lesions in human disease of very varied character. Occasionally in milk and udder of cows. Dust in sick rooms, hospital wards and other contaminated sites.

Habitat: In human infections of many varied types. Occasionally in udder infections of cattle and perhaps other animal sources.

2. **Streptococcus zooepidemicus** Frost and Engelbrecht. (Animal pyogenes, Type A of Edwards, Jour. Bact., *27*, 1934, 527; Frost and Engelbrecht, A Revision of the Genus *Streptococcus*, privately published, 1936, 3 pp. and The Streptococci, 1940, 25; *Streptococcus pyogenes animalis* Seelemann, Deutsche tierarzt. Wchnschr., *50*, 1942, 8 and 48.) From M. L., derived to mean animal *epidemicus*.

Morphology and general cultural characters resemble *Streptococcus pyogenes*. Mucoid colonies are common. Capsules are constantly demonstrable and prominent. Gram-positive.

Gelatin stab: No liquefaction.

Litmus milk: May be curdled, litmus not reduced or slowly after curdling.

Acid from glucose, lactose and sorbitol. Acid may be produced from maltose, sucrose and salicin. No acid

from arabinose, trehalose, raffinose, inulin, glycerol or mannitol.

Does not hydrolyze sodium hippurate, but starch and esculin may be split.

Ammonia is produced from peptone.

Temperature relations: No growth at 10°C or at 45°C. Does not survive 60°C for 30 minutes.

Chemical tolerance: Tolerates 2 per cent NaCl but not 4 per cent and 6.5 per cent. Final pH in glucose broth 4.5 to 5.2. No growth at pH 9.6. Methylene blue 0.01 per cent and 0.1 per cent not tolerated and not reduced.

Action on blood: Beta hemolysis.

Serology: Group C of Lancefield (*loc. cit.*). Cross precipitation with *Streptococcus equi*.

Facultative anaerobe.

Source: Blood stream, inflammatory exudates and lesions of diseased animals. Not known from man.

Habitat: Disease process of domestic and laboratory animals. (Horse: endometritis, foetus. Hog: septicemia. Cow: septicemia, metritis, foetus. Fowls: slipped tendon. Guinea pig: lymphadenitis. Rabbit: septicemia. Fox: pneumonia.)

3. **Streptococcus equi** Sand and Jensen. (*Bacillus adenitis equi* Baruchello, Soc. Veter. de Venetie, Undine, 1886; Giornale di anatomia fisiologica et patologia degli animali domestici, Pisa, Sept., 1887; Sand and Jensen, Deuts. Ztschr. f. Tiermed., *13*, 1888, 436, dated December 27, 1887, Veterinary Congress, Copenhagen, 1887; sometimes incorrectly credited to Schütz, Arch. f. wissens. u. prakt. Tierheilkunde, *14*, 1888, 172; *Streptococcus cappelletti* Chester, Manual Determ. Bact., 1901, 57; *Streptococcus coryzae contagiosae equorum* Schütz, in Eisenberg, Bakt. Diag., 3 Aufl., 1891, 270; *Streptococcus schütz*, Bongert, in Kolle and Wassermann, Handb. d. path. Mikroorg., 2 Aufl., *6*, 1913, 208.) From Latin *equus*, horse.

Possible synonyms: *Streptococcus peritonitidis equi* Hamburger, Cent. f. Bakt., I Abt., *19*, 1896, 882 (*Streptococcus peritonitidis* Migula, Syst. d. Bakt., *2*, 1900, 21); *Streptococcus pyogenes equi* Hutyra, in Lehmann and Neumann, Bakt. Diag., 7 Aufl., 1927, 221.

Note: Rivolta (Dei parassiti vegetali come introduzione allo studio delle malattie parassitarie e delle alterazione dell' alimento degli animali domestici. Turin, 1873, 161) described chains of cocci in *adenitis scrophula equorum, morbus glandulosus*.

Holth, reported by C. O. Jensen (Handb. d. Serumtherapie u. Serum diagnostik in d. Veterinar-med. (Klimmer-Wolff-Eisner), *2*, 1911, 223), and Adsersen (Cent. f. Bakt., I Abt., Orig., *76*, 1915, 111) studied the fermentation reactions of Sand and Jensen's organism. Review of early literature given by Brocq-Rousseau, Forgeot and Urbain (Le streptocoque gourmeux. Revue de Pathologie Comparée et d'Hygiene Générale, Paris, 1925).

Ovoid or spherical cells: 0.6 to 1 micron in diameter, sometimes in pus the long axis of the cells are transverse to the chain, and sometimes in the axis of the chain resembling streptobacilli; bacillary forms are not rare; occur in pairs, short or long chains; very long chains common in broth cultures. Capsules often marked in blood of infected mouse and when grown in serum. Gram-positive.

Gelatin stab: Growth uncertain. No liquefaction.

Nutrient agar: Primary aerobic cultures from pus occasionally fail; growth is poor; small, convex, transparent colonies. Confluent growth is thin, grayish-white or yellowish and more abundant in the condensation water. Growth is increased particularly by horse protein.

Broth: Poor growth even in infusion broth; growth increased by serum (Evans, Jour. Bact., *32*, 1936, 541).

Litmus milk: No change. Not curdled and litmus not reduced.

Acid from glucose, maltose, sucrose and salicin. No acid from arabinose, lactose, trehalose, raffinose, inulin, glycerol, mannitol or sorbitol.

No hydrolysis of sodium hippurate.

Temperature relations: Optimum temperature 37°C. Growth slow at 20°C. No growth at 10°C or 45°C. Does not survive 60°C for 30 minutes.

Chemical tolerance: Does not tolerate 6.5 per cent NaCl; final pH in glucose broth 4.8 to 5.5. Methylene blue is not tolerated 0.01 per cent to 0.1 per cent. Inhibited by bile but not soluble.

Action on blood: On blood-agar, colonies are small and watery, dry out rapidly leaving flat glistening colony. Well-defined wide clear zone of hemolysis (beta hemolysis). Growth in serum broth gives a hemolysin active on horse corpuscles, less so on those of sheep and guinea pig.

Toxin: Subcutaneous injection causes necrosis, other evidence of toxin production is defective.

Fibrinolysin: Usually does not lyse human fibrin; some strains reported to do so.

Serology: A member of Lancefield's Group C (Jour. Exp. Med., *57*, 1933, 571); cross precipitation with Species No. 2 (animal pyogenes) of Edwards (Jour. Bact., *27*, 1934, 527). Cultures have been poor antigens for production of agglutinating serum and results have been unsatisfactory. Immunized rabbit serum may protect mice from infection, to which mice are very susceptible.

Pathogenicity high for white mice, low or no virulence for rabbits and guinea pigs.

Facultative anaerobe; growth in primary culture often better in depth of medium.

Source: Pus from lesions and mucous membrane of upper respiratory tract of horses. Evidence of occurrence in man is unconvincing.

Habitat: Found only in strangles in horses.

4. **Streptococcus equisimilis** Frost and Engelbrecht. (Human C, Ogura, Jour. Jap. Soc. Vet. Sci., *8*, 1929, 174; Edwards, Jour. Bact., *23*, 1932, 259; *ibid.*, *25*, 1933, 527; Sherman, Bact. Reviews, *1*, 1937, 35; Frost and Engelbrecht, A Revision of the Genus *Streptococcus*, privately published, 1936, 3 pp. and The Streptococci, 1940, 45.) From M. L., derived to mean similar to *equi*.

This species is apt to be confused with *Streptococcus equi* Sand and Jensen, but it is not as fastidious in its growth requirements and shows greater tolerance of methylene blue, lyses human fibrin and ferments glycerol and trehalose. It may or may not ferment lactose.

It is also apt to be confused with *Streptococcus pyogenes* Rosenbach except for its greater tolerance of methylene blue, glycerol fermentation and especially Lancefield's serological grouping (Jour. Exp. Med., *57*, 1933, 371).

Spheres: Gram-positive.

Gelatin: Not liquefied.

Litmus milk: Acid, may be curdled; litmus not reduced before curdling.

Acid from glucose, maltose, sucrose, trehalose and glycerol; may or may not form acid from lactose and salicin. No acid from arabinose, raffinose, inulin, mannitol or sorbitol.

No hydrolysis of sodium hippurate but may hydrolyze starch and esculin.

Ammonia is produced from peptone.

Temperature relations: No growth at 10°C and 45°C. Does not survive 60°C for 30 minutes.

Chemical tolerance: Does not tolerate 6.5 per cent NaCl. Final pH in glucose broth 5.4 to 4.6; no growth at pH 9.6. Methylene blue 0.1 per cent not tolerated, but Edwards (Kentucky Agr. Exp. Station Bull. 356, 1935; confirmed by Davis and Guzdar, Jour. Path. and Bact., *43*, 1936, 197) finds resistance to 0.000025 molar methylene blue in infusion-casein digest broth. Rarely grows on 40 per cent bile-blood agar.

Action on blood: Beta hemolysis.

Fibrinolysin: Dissolves human fibrin.

Serology: Lancefield (*loc. cit*) Group C.

Facultative anaerobe.

Source: Human nose and throat, vagina and skin; erysipelas and puerperal fever. Uncommon in domestic animals and usu-

ally associated with other streptococci (Edwards, *loc. cit*).

Habitat: Human upper respiratory tract and vagina.

Streptococcus dysgalactiae Diernhofer (Milchw. Forsch., *13*, 1932, 368), Group II Minett (Proc. 12th Internat. Vet. Cong., *2*, 1934, 511) and *Streptococcus pseudoagalactiae* Plastridge and Hartsell (Jour. Inf. Dis., *61*, 1931, 114) appear to be identical (Little, personal communication). Physiologically these organisms are like Human C types (*Streptococcus equisimilis* Frost and Engelbrecht) except that they are not hemolytic.

5. **Streptococcus agalactiae** Lehmann and Neumann. (Streptococcus de la mammite, Nocard and Mollereau, Ann. Inst. Past., *1*, 1887, 109; *Streptococcus nocardi* Trevisan, I generi e le specie delle Batteriacee, 1889, 36 (this name rightly has priority and is valid but has remained unused and it would seem unwise to adopt it in place of a name familiar by usage); *Streptococcus mastitis sporadicae* Guillebeau and *Streptococcus mastitis contagiosae* Guillebeau, Landw. Jahrb. d. Schweiz, *4*, 1892, 27; abst. in Cent. f. Bakt., *12*, 1892, 101; *Streptococcus agalactiae contagiosae* Kitt, Bakterienkunde, Wien, 1893, 322; Lehmann and Neumann, Bakt. Diag., 1 Aufl., *2*, 1896, 126; *Streptococcus mastitidis* Migula, Syst. d. Bakt., *2*, 1900, 19.) From Greek, want of milk.

According to Hucker and Harrison (N. Y. Agr. Exp. Sta. Tech. Bul. 246, 1937, 9), *Streptococcus agalactiae* Lehmann and Neumann is identical with Group I of Minett, Stableforth and Edwards (Jour. Comp. Path. and Ther., *46*, 1933, 131) and Group A of Plastridge, Anderson, Brigham and Spaulding (Conn. (Storrs) Agr. Exp. Sta. Bul. 195, 1934).

Description largely taken from Hansen, N. Y. Agr. Exp. Sta. Tech. Bul. 232, 1935.

Spherical or ovoid cells: 0.4 to 1.2 microns in diameter, occurring in chains of seldom less than four cells and frequently very long; the longer axis of the cells may be in the axis of the chain or may be transverse to it. Chains may appear to be composed of paired cocci. Capsules(?). Gram-positive.

Gelatin stab: Gray, filiform growth. No liquefaction.

Nutrient agar: Small gray colonies.

Broth: Growth is variable in character; most frequently a sticky, flaky deposit which may adhere to the side of the tube but the supernatant fluid is clear; long chains are formed.

Starch broth: May produce yellow to orange sediment.

Litmus milk: Acid followed by curdling. Litmus reduced subsequent to curdling and proceeds from the bottom upwards. Little or no proteolysis.

Indole not formed.

Acid from glucose, maltose, galactose, fructose, lactose, sucrose, mannose, dextrin and trehalose and at times from salicin. No acid from arabinose, raffinose, inulin, xylose, mannitol, sorbitol or amygdalin. Slight amount of acid from glycerol.

Sodium hippurate is hydrolyzed. No hydrolysis of starch and esculin.

Nitrites not produced from nitrates.

Ammonia is produced from peptone.

Temperature relations: Optimum temperature 37°C. Range of growth tolerance between 15°C and 40°C. No growth at 10°C or 45°C. Does not survive 60°C for 30 minutes.

Chemical tolerance: Tolerates 2 per cent NaCl, variable tolerance of 4 per cent NaCl and does not tolerate 6.5 per cent NaCl. Final pH in glucose broth 4.2 to 4.6; no growth at pH 9.6. Methylene blue 0.01 per cent and 0.1 per cent not tolerated and not reduced.

Not soluble in bile and is not inhibited by 10 per cent and usually not by 40 per cent bile.

Action on blood: Variable; between ⅓ and ½ of the strains produce a narrow clear zone of hemolysis; certain strains described as producing greening. The hemolytic strains produce an oxygen-stable, filterable hemolysin.

Toxin: No evidence of an erythrogenic toxin.

Fibrinolysin: Does not dissolve human fibrin.

Serology: Group B of Lancefield (Jour. Exp. Med., *47*, 1933, 571). Three antigenic types have been separated which appear to be associated with the carbohydrate and not the protein fraction.

Facultative anaerobe.

Source: Isolated from milk and tissues from udders infected with mastitis. Occasionally reported from human sources (Lancefield, Jour. Exp. Med., *57*, 1933, 571; Hare, Jour. Path. Bact., *41*, 1935, 499).

Habitat: Udder of cattle with mastitis.

6. **Streptococcus salivarius** Andrewes and Horder. (Lancet, *2*, 1906, 712; *Streptococcus cardio-arthritidis* Small, Amer. Jour. Med. Sci., *173*, 1927, 103.) From Latin *salivarius*, slimy, clammy; M. L., related to saliva.

Description based on studies by Safford, Sherman and Hodge, Jour. Bact., *33*, 1937, 263 and Sherman, Niven and Smiley, Jour. Bact., *45*, 1943, 249.

Spherical or ellipsoidal cells, 0.6 to 0.8 micron in diameter, usually in short chains. Long axis of cell lies in axis of chain. Cells are relatively large in liquid media, especially milk. Gram-positive.

Gelatin stab: Filiform growth. No liquefaction.

Plain nutrient agar: Colonies white, small, not more than 0.5 mm in diameter. Notwithstanding rather vigorous growth on artificial culture media, cultures die out readily.

Nutrient agar containing 5 per cent sucrose or raffinose produces a large, clear, soft, mucoid colony about the diameter of those produced by coliform bacteria and yeasts. This is quite distinctive as no other known species of streptococcus (except occasional strains of *Streptococcus bovis*) produce colonies of this type on sucrose or raffinose agar. The polysaccharide produced is a soluble levan, some strains producing in addition a smaller amount of insoluble dextran (the polysaccharide in the *Streptococcus bovis* colonies is a dextran).

Action on blood agar: Indifferent (gamma hemolysis of Brown, Rockefeller Inst. Med. Res., Monograph 9, 1919, 8). No soluble toxin and no hemolysin has been demonstrated

Broth: Variable. Loose, flocculent deposit with clear supernatant fluid and long chains, or uniform or granular turbidity with small deposit and short chains. No pellicle.

Litmus milk: Acidified and curdled promptly by all lactose-fermenting strains. Completely reduced but only after curdling. No digestion.

Potato: Slight growth. Difficult to detect.

Acid from glucose, maltose, sucrose, raffinose, inulin and salicin. No acid from glycerol, mannitol, sorbitol, arabinose or xylose. Trehalose and lactose usually fermented.

No hydrolysis of sodium hippurate and arginine. Splits esculin. Starch is not hydrolyzed.

Ammonia is not produced from peptone.

Chemical tolerance: Tolerates 2 per cent but not 4 per cent NaCl. Final pH in glucose broth between 4.4 and 4.0. No growth at pH 9.6. Methylene blue 0.01 per cent and 0.1 per cent not tolerated. Not soluble in bile but inhibited by 30 per cent bile in blood agar.

Catalase not produced.

Temperature relations: Optimum growth 37° to 43°C. Growth at 45°C. No growth at 47°C. No growth at 10°C. Does not survive 60°C for 30 minutes.

Facultative anaerobe.

Serology: No group antigen has been demonstrated. Contains several serological types.

Source: Saliva and sputum in various pulmonary infections, apical abscesses of teeth, carious lesions of teeth, intestinal tract.

Habitat: Human mouth, throat and nasopharynx.

7. **Streptococcus mitis** Andrewes and Horder. (Lancet, *2*, 1906, 712.) From Latin *mitis*, mild.

Synonyms: *Streptococcus mitior* seu *viridans* Schottmüller, Münch. med. Wchnschr., *50*, 1903, 849 (these names refer to a group of species and they are therefore confused in meaning in medical literature. See Winslow and Winslow, The Systematic Relationships of the Coccaceae. New York, 1908, and Safford, Sherman and Hodge, Jour. Bact., *33*, 1937, 263). The name *Streptococcus mitis* was first proposed by Fränkel (Münch. med. Wchnschr., *52*, 1904, 548 and 1868). Because others have used this name with varied meanings (*Streptococcus mitis* seu *viridans* von Lingelsheim, in Kolle and Wassermann, Handb. d. path. Mikroorg., 2 Aufl., *4*, 1912, 453; *Streptococcus mitis* Holman, Jour. Med. Res., *34*, 1916, 377), the more definite emendation of Andrewes and Horder has been used as the basis of the description given here. The relationships of these organisms has been discussed by Brown, Rockefeller Inst. Med. Res., Monograph No. 9, 1919, 86.

Description based on studies by Safford, Sherman and Hodge (*loc. cit.*) and Sherman, Niven and Smiley, Jour. Bact., *45*, 1943, 249.

Spherical or ellipsoidal cells, 0.6 to 0.8 micron in diameter. Long axis of cell lies in axis of chain. Cells not especially large in liquid media including milk. No capsules. Gram-positive.

Gelatin stab: Filiform growth. No liquefaction.

Nutrient agar: Growth increased when serum or blood is added. Confluent growth, gray and abundant.

Action on blood agar: The colonies are surrounded by a characteristic greening (alpha hemolysis of Brown, Rockefeller Inst. Med. Res., Monograph 9, 1919, 8). This is weak with some strains and is variable under anaerobic conditions. No soluble toxin and no hemolysin has been demonstrated.

Broth: Variable. Loose, flocculent deposit with clear supernatant fluid and long chains, or granular turbidity with small deposit and short chains. No pellicle.

Litmus milk: Usually acidified and curdled promptly; litmus is completely reduced but only after curdling; no digestion.

Potato: Slight growth which is difficult to detect.

Acid from glucose, maltose, lactose, sucrose and usually salicin. Variable fermentation of raffinose. No acid from inulin, mannitol, sorbitol, glycerol, arabinose or xylose. Trehalose rarely fermented.

No hydrolysis of sodium hippurate and usually no hydrolysis of arginine. Action on esculin usually negative.

Usually ammonia is not produced from peptone.

Chemical tolerance: Tolerates 2 per cent but not 4 per cent NaCl. Final pH in glucose broth 5.8 to 4.2, ave. 4.5. No growth at pH 9.6. Methylene blue 0.01 per cent and 0.1 per cent not tolerated. Not soluble in bile but inhibited by 30 per cent bile in blood agar.

Catalase not produced.

Temperature relations: Optimum growth 37° to 40°C. Many strains do not grow at 45°C. No growth at 10°C. Does not survive 60°C for 30 minutes.

Facultative anaerobe.

Serology: No group antigen has been demonstrated. Contains several serological types.

Source: Saliva and sputum in various pulmonary infections, pus from upper respiratory tract and sinuses, blood and various organs in sub-acute endocarditis.

Habitat: Human mouth, throat and nasopharynx.

8. **Streptococcus bovis** Orla-Jensen *emend.* Sherman. (Orla-Jensen, The Lactic Acid Bacteria, 1919, 137; Sherman, Bacteriological Reviews, *1*, 1937, 57.) From Latin *bos*, cow.

The majority of the strains of *Strepto-*

coccus inulinaceus may be considered as identical with *Streptococcus bovis* as described here. The so-called Bargen streptococcus (Bargen, Jour. Amer. Med. Assn., *83*, 1924, 332; Arch. Int. Med., *45*, 1930, 559) is also considered to be *Streptococcus bovis*.

Spheres: Occurring in pairs and chains. Capsulated in milk. Gram-positive.

Gelatin stab: No liquefaction.

Litmus milk: Acid, curdled in 3 to 5 days, followed by reduction of the litmus.

Acid from glucose, fructose, mannose, galactose, maltose, lactose, sucrose, raffinose and salicin; sometimes from mannitol, sorbitol, inulin, arabinose and trehalose. Not from glycerol.

Starch is hydrolyzed by typical strains but not by variety *inulinaceus*. Esculin is hydrolyzed but not sodium hippurate.

Nitrites not produced from nitrates.

Ammonia not produced from 4 per cent peptone.

Temperature relations: Optimum temperature 35°C. When freshly isolated, maximum 45°C. No growth at 22°C or below. Survives 60°C for 30 minutes, but not 65°C.

Chemical tolerance: 2 per cent NaCl growth, 4 per cent NaCl no growth, 6.5 per cent NaCl no growth. Final pH in glucose broth 4.5 to 4.0. No growth at pH 9.6. May tolerate 0.01 per cent methylene blue but not 0.1 per cent. Tolerant of bile and not soluble.

Action on blood: Not hemolytic; the changes exhibited vary from greening (alpha) to no observable change (gamma).

Soluble hemolysin: Absent.

Toxin: Absent.

Serology: Some cross reaction with Lancefield Group D (Sherman, Jour. Bact., *35*, 1938, 81).

Facultative anaerobe.

Distinctive characters: Greening or no change in blood; a higher maximum temperature of growth than *Streptococcus salivarius* and distinctly higher thermal resistance (60°C for 30 minutes); hydrolysis of starch and usually ferments arabinose and sometimes mannitol.

Source: Saliva, feces and intestinal contents of cattle; milk of cows; sometimes abundantly present in human feces (Bargen's coccus) in health and disease. The variety *inulinaceus* is sometimes abundant in the bovine throat.

Habitat: Bovine mouth and alimentary tract where it is the predominating streptococcus.

9. **Streptococcus thermophilus** Orla-Jensen. (Maelkeri-Bacteriologi, 1916, 37; The Lactic Acid Bacteria, 1919, 136.) From Greek *thermus*, heat; *philus*, loving.

Spheres: 0.7 to 0.9 micron, with pointed ends, occurring singly and in short chains. Gram-positive.

Gelatin stab: No liquefaction.

Nutrient agar: Small, pin-point, gray, circular colonies. In streak cultures growth is scanty, beaded and gray. Fastidious in nutritive requirements needing appropriate carbohydrates added to peptone-infusion media (especially lactose and sucrose). Viability on laboratory media low.

Broth: Fine granular sediment; usually in very long chains, especially at 45°C.

Litmus milk: Acid, curdled, followed by partial reduction of the litmus.

Acid from glucose, fructose, lactose, and sucrose; seldom ferments raffinose and arabinose. No acid from maltose, dextrin, inulin, glycerol, mannitol, sorbitol or salicin.

No hydrolysis of sodium hippurate or esculin. Starch may be hydrolyzed on a favorable medium.

Ammonia not formed from 4 per cent peptone.

Temperature relations: Optimum 40° to 50°C. Minimum 20°C. No growth at 53°C. Survives 60° and 65°C for 30 minutes. Thermal death point 72° to 74°C.

Chemical tolerance: Extremely sensitive to salt, no growth with 2 per cent, 4 per cent and 6.5 per cent NaCl. Final pH in glucose broth 4.5 to 4.0. No growth

at pH 9.6. Not tolerant of 0.01 per cent and 0.1 per cent methylene blue.

No action on blood.

Serology: No cross reaction with Lancefield Group D (Sherman, Jour. Bact., *35*, 1938, 81).

Facultative anaerobe.

Distinctive characters: High growth temperature (50°C) and heat resistance (60° to 65°C). Inability to ferment maltose and salicin. Inhibited by 2 per cent NaCl. Nutritive requirements in medium.

Source: Milk and milk products. Used as a starter in making Swiss cheese.

10. **Streptococcus equinus** Andrewes and Horder. (Lancet, *2*, 1906, 712.) From Latin *equinus*, of horses.

Spheres: Occurring in short chains; the chains are longer in broth than in milk and some cultures give extremely long chains in broth. Gram-positive.

Gelatin stab: Little or no growth at 20°C. Not liquefied.

Litmus milk: No visible change, grows poorly (with 2 per cent added glucose there is little reduction of litmus).

Acid from glucose, fructose, galactose, maltose and usually from sucrose and salicin; raffinose and inulin are seldom fermented; arabinose, xylose, lactose, mannitol and glycerol are not fermented. The salicin-negative strains correspond to *Streptococcus ignavus* Holman, Jour. Med. Res., *34*, (N. S. *29*), 1916, 377.

Starch is not hydrolyzed under ordinary conditions of test (poured plate); it may be hydrolyzed by streak cultures on a very favorable medium. Sodium hippurate is not split. Esculin is hydrolyzed slowly, failure in three days, becomes positive in seven.

Ammonia not produced from 4 per cent peptone.

Temperature relations: Minimum 21°C. Growth at 45°C, seldom at 47°C, and no growth at 48°C. Sometimes survives 60°C for 30 minutes.

Chemical tolerance: Growth in 2 per cent NaCl but not in 4 per cent and 6.5 per cent. Final pH in glucose broth 4.5 to 4.0; no growth at pH 9.6. Some strains tolerate 0.01 per cent but none tolerate 0.1 per cent methylene blue.

Action on blood: Greening (alpha on horse blood) varying to weak but definite. No hemolysis.

Serology unknown, but no cross reaction with Lancefield Group D (Sherman, Jour. Bact., *35*, 1938, 81).

Facultative anaerobe.

Distinctive characters: Minimum temperature of growth (20°C) and high maximum temperature of growth (47°C); poor growth in milk, even with added glucose; failure to ferment lactose.

Sources: Human and bovine feces; human mouth, urine and inflammatory exudates (pathogenicity not established). Andrewes and Horder (*loc. cit.*) failed to find it in feces of fox and stoat.

Habitat: Predominating organism in the intestine of horses.

11. **Streptococcus lactis** (Lister) Löhnis. (*Bacterium lactis* Lister, Quart. Jour. Micro. Sci., *13*, 1873, 380; *18*, 1878, 177; Löhnis, Cent. f. Bakt., II Abt., *22*, 1909, 553.) From Latin *lac*, milk.

The following organisms are generally regarded as identical with *Streptococcus lactis* Löhnis. See Breed, in Jordan and Falk, The Newer Knowledge of Bacteriology and Immunology, Chicago, 1928, 383.

Streptococcus acidi lactici Grotenfelt, Fortschr. d. Med., *7*, 1889, 121; *Micrococcus acidi paralactici* Nencki and Sieber, Monatschr. f. Chem., *10*, 1889, 532; Bacillus No. 19, Adametz, Landw. Jahrb., *18*, 1889, 227; Eine bestimmte Bacterienart, Günther and Thierfelder, Arch. f. Hyg., *25*, 1895, 164; *Bacillus acidi lactici* Esten, Storrs Agric. Exper. Sta. Conn., Ann. Rep. for 1896, 1897, 44 (not Milchsäurebacterium, Hueppe, Mitt. d. kais. Gesundheitsamte, *2*, 1884, 340, which is *Bacillus acidi lactici* Zopf, Die Spaltpilze, 3 Aufl., 1885, 87); *Bacterium güntheri* Lehmann and Neumann, Bakt. Diag., 1 Aufl., *2*, 1896, 197; *Bacterium*

lactis acidi Leichmann, Cent. f. Bakt., II Abt., *2*, 1896, 777 (not *Bacterium lactis acidi* Marpmann, Ergänzungshefte Cent. f. allgem. Gesundheitspflege, *2*, 1886, 117); Der ovaler Coccus, Freudenreich, Cent. f. Bakt., II Abt., *1*, 1896, 168; *Bacillus lacticus* Kruse, in Flügge, Die Mikroorganismen, 3 Aufl., *2*, 1896, 356; *Bacterium lacticus* Chester, Del. Agr. Exp. Sta., 9th Ann. Rept., 1897, 88; *Bacillus acidi paralactici* Kozai, Ztschr. f. Hyg., *31*, 1899, 372; *Streptococcus paralacticus* Migula, Syst. d. Bakt., *2*, 1900, 18; *Bacterium lacticum* Migula, Syst. d. Bakt., *2*, 1900, 405; *Bacterium truncatum* Migula, Syst. d. Bakt., *2*, 1900, 407 (Bacillus No. 19 of Adametz; *Bacterium punctatum* Chester, Man. Determ. Bact., 1901, 147; not *Bacterium truncatum* Chester, *ibid.*, 157; not *Bacterium truncatum* Chester, *ibid.*, 195); *Streptococcus grotenfeltii* Chester, Manual Determ. Bact., 1901, 67; *Lactococcus lactis* Beijerinck, Arch. Neérl. d. Sci. Exact. et Nat., Sér. II, *7*, 1901, 213; *Streptococcus lacticus* Kruse, Cent. f. Bakt., I Abt., Orig., *34*, 1903, 737; *Streptococcus güntheri* Lehmann and Neumann, Bakt. Diag., 4 Aufl., *2*, 1907, 242; *Bacillus lactis acidi* Sewerin, Cent. f. Bakt., II Abt., *22*, 1908, 8 (not *Bacillus lactis acidi* Marpmann, *loc. cit.*, 120, nor Leichmann, *loc. cit.*, 778); *Bacterium leichmanni* Wolff, Cent. f. Bakt., II Abt., *24*, 1909, 57.

Spheres: Many cells elongated in direction of chain; 0.5 to 1 micron; mostly pairs and short chains, with some cultures long chains. Gram-positive.

Gelatin stab: Filiform to beaded growth. No liquefaction.

Nutrient agar colonies: Small, round or oval, gray, entire, slightly raised. Streak culture tends to remain as definite colonies throughout, confluent in parts.

Glucose broth: Turbidity and later sediment.

Potato: No visible growth.

Litmus milk: Acid; complete reduction of litmus before curdling. Young cultures entirely reduced with narrow red band at top which widens with ageing. No digestion and no gas produced, but whey may be expressed.

Acid from glucose, maltose and lactose; variable in arabinose, xylose, maltose, sucrose, mannitol and salicin. No acid from raffinose, inulin, glycerol or sorbitol. Occasional strains have been noted which fail to ferment lactose (Yawger and Sherman, Jour. Dairy Sci., *20*, 1937, 83) and others which do ferment raffinose (Orla-Jensen and Hansen, Cent. f. Bakt., II Abt., *86*, 1932, 6).

Starch not hydrolyzed. Sodium hippurate may be hydrolyzed and esculin is split.

Ammonia is produced from 4 per cent peptone.

Temperature relations: No growth at 45°C. Some strains survive 60°C for 30 minutes.

Chemical tolerance: Growth with 2 per cent and 4 per cent NaCl but not with 6.5 per cent. Final pH in broth 4.5 to 4.0. No growth at pH 9.6 but grows at pH 9.2. Tolerates both 0.01 per cent, 0.1 per cent and 0.3 per cent methylene blue. Bile neither lyses nor inhibits growth.

Action on blood: No hemolysis; may show greening or no action.

Serology: Sherman, Smiley and Niven (Jour. Dairy Sci., *23*, 1940, 529) have produced a species-specific group serum for this species. Shattock and Mattick (Jour. Hyg., *43*, 1943, 173) have designated this group as Group N. The above authors are in agreement in feeling that their studies indicate a close serological relationship between *Streptococcus lactis* and *Streptococcus cremoris*. Toxin not known.

Facultative anaerobe.

Distinctive characters: Growth at 10°C or below and at 40°C but not at 45°C; rapid complete reduction of litmus before curdling milk; growth in presence of 4 per cent but not 6.5 per cent NaCl; ammonia produced from peptone; no growth at pH 9.6 but grows at pH 9.2.

Source: Isolated from milk by Lister (*loc. cit.*). Milk and milk products.

Habitat: Not in the udder of cows. Plants may be natural habitat (Stark and Sherman, Jour. Bact., *30*, 1935, 639).

NOTE: The following may be regarded as varieties of *Streptococcus lactis:* (1) *Streptococcus lactis* var. *maltigenes* Hammer and Cordes, Iowa Agr. Exp. Sta. Res. Bull. 68, 1921; (2) *Streptococcus lactis* var. *anoxyphilus* Hammer and Baker, Iowa Agr. Exp. Sta. Res. Bull. 99, 1926; (3) *Streptococcus lactis* var. *tardus* Hammer and Baker, *ibid.* Also (4) *Streptococcus amylolactis*, (5) *Streptococcus raffinolactis* and (6) *Streptococcus saccharolactis* Orla-Jensen and Hansen, Cent. f. Bakt., II Abt., *86*, 1932, 6.

12. **Streptococcus cremoris** Orla-Jensen. (The Lactic Acid Bacteria, 1919, 132.) From Latin *cremor*, thick juice; M. L., cream.

Synonyms: ? *Streptococcus hollandicus* Wiegmann, in Kramer, Die Bakteriologie in ihren Beziehungen zur Landwirtschaft und den Landw. Technischen Gewerben, Wien, 1890; *Streptococcus lactis B*, Ayers, Johnson and Mudge, Jour. Inf. Dis., *34*, 1934, 29.

Spheres: 0.6 to 0.7 micron (often larger than *Streptococcus lactis*); forming long chains, especially in milk, some cultures in pairs. Gram-positive.

Gelatin stab: No liquefaction.

Litmus milk: Acid; complete reduction of litmus before curdling with red line at top broadening with age; clot separates with no digestion of casein; milk becomes slimy.

Acid from glucose and lactose; may ferment maltose, salicin and rarely sucrose, raffinose and mannitol. Arabinose, xylose, sorbitol, inulin and glycerol are not fermented.

No hydrolysis of starch and sodium hippurate but sometimes esculin.

Ammonia not produced from 4 per cent peptone.

Temperature relations: Optimum below 30°C. Minimum 10°C. Maximum 37°C. May survive 60°C for 30 minutes. Thermal death point 65°C to 70°C.

Chemical tolerance: Grows with 2 per cent but not with 4 per cent and 6.5 per cent NaCl. Final pH in glucose broth 4.6 to 4.0. No growth at pH 9.6 and 9.2. Tolerates 0.01 per cent and sometimes 0.1 and seldom 0.3 per cent methylene blue.

Action on blood: No hemolysis.

Facultative anaerobe.

Distinctive characters: Inability to grow at 40°C; reduction of litmus before curdling milk; no growth in the presence of 4 per cent NaCl and at pH 9.2; does not grow well on artificial media.

Source: Raw milk and milk products; commercial starters in butter and cheese factories. Not known from human and animal sources.

The following may be regarded as varieties of *Streptococcus cremoris:* (1) *Streptococcus lactis* var. *hollandicus* Buchanan and Hammer, Iowa Agr. Exp. Sta. Res. Bull. 22, 1915; (2) *Streptococcus mannitocremoris* Orla-Jensen and Hansen, Cent. f. Bakt., II Abt., *86*, 1932, 6.

13. **Streptococcus faecalis** Andrewes and Horder. (*Micrococcus ovalis* Escherich, Die Darmbakterien, Stuttgart, 1886, 89; Entérocoque, Thiercelin, Compt. rend. Soc. Biol., Paris, *54*, 1902, 1082; *Enterococcus proteiformis* Thiercelin and Jouhaud, Compt. rend. Soc. Biol., Paris, *55*, 1903, 686; Andrewes and Horder, Lancet, *2*, 1906, 708; *Streptococcus faecium* and *Streptococcus glycerinaceus* Orla-Jensen, The Lactic Acid Bacteria, 1919, 139 and 140; *Diplococcus enterococcus* Neveu-Lemaire, Précis Parasitol. Hum., 5th ed., 1921, 18; *Streptococcus ovalis* Lehmann and Neumann, Bakt. Diag., 7 Aufl., *2*, 1927, 209 and 230; *Streptococcus proteiformis* Hauduroy et al., Dict. d. Bact. Path., Paris, 1937, 520.) From Latin *faex*, dregs, residue; M. L., feces, excrement; M. L. *faecalis*, fecal.

Escherich reclassified his *Micrococcus*

ovalis (*loc. cit.*) as a streptococcus in Jahrb. f. Kinderheilk., *49*, 1899, 161.

According to Gorini (Le Lait, *6*, 1936, 81) his term *Gastrococcus* is a synonym of *Enterococcus* Thiercelin (*loc. cit.*), *Micrococcus ovalis* Escherich (*loc. cit.*) and *Streptococcus faecalis* Andrewes and Horder (*loc. cit.*).

Spheres, ovals, of variable size (often large), usually occurring in pairs and sometimes short chains in fluid media. Gram-positive.

Gelatin stab: Filiform growth. No liquefaction.

Nutrient agar: Small, round, raised, milky colonies. Streak culture fairly abundant and confluent.

Broth: Turbid, clearing later with abundant sediment.

Potato: No visible growth.

Litmus milk: Acid, usually reduction of litmus before curdling; no digestion of clot.

Acid from glucose, maltose, lactose, salicin and almost always mannitol; may or may not ferment arabinose, sucrose, raffinose, glycerol, sorbitol. Inulin is seldom fermented.

Starch not hydrolyzed; sodium hippurate may be and esculin is hydrolyzed.

Ammonia is produced from 4 per cent peptone.

Temperature relations: Optimum 37°C. May grow at 5°C and below. Grows at 10°C and 45°C, seldom grows at 50°C. Survives 62.8°C for 30 minutes.

Chemical tolerance: Tolerates 2 per cent, 4 per cent and 6.5 per cent NaCl. Final pH in glucose broth 4.4 to 4.0. Grows at pH 9.6. Tolerates 0.01 per cent and 0.1 per cent methylene blue. Bile does not lyse or inhibit growth.

Action on blood: Usually greening; sometimes no change.

Toxin unknown.

Serology: Lancefield's Group D (Sherman, Jour. Bact., *35*, 1938, 81).

Facultative anaerobe.

Distinctive characters: Growth at 10°C and 45°C; survives 60°C for 30 minutes; reduction of litmus before curdling milk; growth at pH 9.6, in the presence of 6.5 per cent NaCl, and 0.1 per cent methylene blue; not hemolytic and does not liquefy gelatin.

Source: Human feces and intestinal contents; inflammatory exudates; blood stream in subacute endocarditis; European foul-brood of bees; milk and milk products, especially cheese; garden plants.

Habitat: Human intestine, milk and milk products.

14. **Streptococcus liquefaciens** Sternberg *emend.* Orla-Jensen. (Sternberg, Manual of Bacteriology, 1893, 613; Orla-Jensen, The Lactic Acid Bacteria, 1919, 142). From Latin *liquefaciens*, liquefying.

Synonyms: *Micrococcus casei amari* Freudenreich, Landw. Jahrb. d. Schweiz, *8*, 1894, 136; *Streptococcus apis* Maassen, Arb. Biol. Abt. f. Land- u. Forstwirtsch. a.d.k. Gesundheitsamte, *6*, 1908, 53 (as shown by Hucker, N. Y. Agr. Exp. Sta. Tech. Bull. 143, 1928, 40 and 190, 1932, 17); *Bacillus güntheri* Cowan, British Bee-Keepers Guide Book, 20th ed., London, 1911, 171; *Streptococcus coli gracilis* Escherich, Die Darmbakterien des Säuglings und ihre Beziehungen zur Physiologie der Verdauung, 1886, 77 (*Streptococcus gracilis* Lehmann and Neumann, Bakt. Diag., 1 Aufl., *2*, 1896, 118).

As explained by Hucker (N. Y. Agr. Exp. Sta. Tech. Bull. 144, 1928, 6), some of the acid proteolytic cocci first described by Gorini in 1902 (*loc. cit.*) are gelatin-liquefying streptococci identical with *Streptococcus liquefaciens*. Also see Long and Hammer, Iowa Agr. Exp. Sta. Res. Bull. 206, 1936, 219. The following names have been used for these streptococci: Bactéries productrices d'acide et de présure, Gorini, Rev. gén. du Lait, *1*, 1902, 173; *Micrococcus casei liquefaciens* Orla-Jensen, Cent. f. Bakt., II Abt., *13*, 1904, 430; *Micrococcus casei acido-proteolyticus I* (liquefies gelatin) and *Micro-*

coccus casei acido-proteolyticus II (does not liquefy gelatin) Gorini, Rev. gén. du Lait, *8*, 1910, 337 (*Micrococcus casei proteolyticus I* and *II* Gorini, Rend. Accad. Lincei, Ser. 5, *19*, 1910, II Sem., 150); *Coccus acido-proteolyticus casei I* and *Coccus acido-proteolyticus casei II* Gorini, Rev. gén. du Lait, *9*, 1912, 97. The terms *Mammococcus* and *Caseococcus* have also been used for these cocci by Gorini, Le Lait, *6*, 1926, 81; *Mammococcus acidoproteolyticus* Gorini, Act. P. Accad. Sci. Nov. Lync., Vatican City, *88*, I Sess., 1934, 42.

Spheres: Usually in pairs, sometimes short chains. Gram-positive.

Gelatin stab: Liquefaction and profuse growth; liquefaction fails in occasional variants but these are nevertheless Lancefield group D and have the other characters of the species. (See Sherman, Stark and Mauer, Jour. Bact., *33*, 1937, 492.)

Litmus milk: Acid; curdled and peptonized; the litmus is reduced completely before acidulation and curdling; caseolysis fails in variants not liquefying gelatin (Sherman, Stark and Mauer, *loc. cit.*, 486). Gives milk bitter taste.

Acid from glucose, maltose, sucrose, lactose, trehalose, mannitol, sorbitol, salicin and glycerol (rare failure from sucrose and glycerol); variable fermentation of arabinose and raffinose. Inulin not fermented.

Starch not hydrolyzed, sodium hippurate may be and esculin is hydrolyzed.

Ammonia is produced from 4 per cent peptone.

Temperature relations: Growth at 10°C and 45°C, occasional growth at 50°C. Survives 60°C and 62.8°C for 30 minutes.

Chemical tolerance: Tolerates 2, 4 and 6.5 per cent NaCl; final pH in glucose broth 4.5 to 4.0; growth at pH 9.6; tolerates 0.01 per cent and 0.1 per cent methylene blue. Bile tolerant.

Action on blood: No change or greening (alpha). Human fibrin not lysed.

Serology: Lancefield Group D (Sherman, Jour. Bact., *35*, 1938, 81).

Facultative anaerobe.

Distinctive characters: Growth at 10°C and 45°C; resistance to 60°C; growth in presence of 6.5 per cent NaCl, 0.1 per cent methylene blue and at pH 9.6. Ammonia produced from peptone. Strong reduction of litmus before acidulation of milk, which is afterwards curdled and peptonized; gelatin is liquefied; marked proteolysis. Low final pH in glucose broth. Fermentation of glycerol and mannitol.

Source: Originally isolated by Sternberg from a cadaver. Dairy and other food products. Foul brood of bees. Plants, feces, human vagina, blood in subacute endocarditis.

Habitat: Human and animal intestine.

15. **Streptococcus zymogenes** (MacCallum and Hastings) Holland. (*Micrococcus zymogenes* MacCallum and Hastings, Jour. Exp. Med., *4*, 1899, 521; Holland, Jour. Bact., *5*, 1920, 226; *Staphylococcus zymogenes* Ford, Textb. of Bact., 1927, 425.) From Greek *zyme*, ferment and *-genes*, producing.

This species shows the same characteristics as *Streptococcus liquefaciens* except as given below. The two species have sometimes been regarded as identical (Bergey et al., Manual, 3rd ed., 1930, 59).

Gelatin stab: May or may not liquefy gelatin. Otherwise as in *Streptococcus liquefaciens*.

Action on blood: Beta hemolytic.

Source: Originally isolated from an acute case of endocarditis.

Habitat: Human and animal intestine.

16. **Streptococcus durans** Sherman and Wing. (*Streptococcus hemothermophilus* Sherman and Wing, Jour. Dairy Sci., *18*, 1935, 657; original name withdrawn by Sherman and Wing, Jour. Dairy Sci., *20*, 1937, 165.) From Latin *durans*, resisting.

Spheres: Occurring in pairs and short chains, more rarely in long chains. Gram-positive.

Gelatin stab: No liquefaction.

Litmus milk: Acid; curdled, followed by reduction of litmus.

Acid from glucose, maltose, lactose, and usually salicin and trehalose. Raffinose, inulin, sorbitol, arabinose, glycerol not fermented and mannitol and sucrose rarely fermented.

Starch not hydrolyzed. Sodium hippurate and esculin are hydrolyzed.

Ammonia is produced from 4 per cent peptone.

Temperature relations: Growth at 10°C. Maximum 50°C. Survives heating for 30 minutes at 62.8°C and usually 65.6°C.

Chemical tolerance: Growth with 2 per cent, 4 per cent and 6.5 per cent NaCl. Final pH in glucose broth 4.5 to 4.0. Growth at pH 9.6. Tolerates 0.01 per cent and 0.1 per cent methylene blue.

Action on blood: Active hemolysis of beta type (horse, human and rabbit blood); persistent after 5 years culture on media without blood.

Toxin unknown. Non-pathogenic for mice, rabbits and guinea pigs.

Serology: Lancefield's Group D (Sherman, Jour. Bact., *35*, 1938, 81).

Facultative anaerobe.

Distinctive characters: Growth at 10°C and 45°C; beta hemolysis; failure to ferment sucrose and mannitol; resistance to 60°C for 30 minutes; tolerance of 0.1 per cent methylene blue and 6.5 per cent NaCl.

Source: Forty strains were isolated from spray process milk powder.

Habitat: Human intestine; milk and milk products.

*17. **Streptococcus anaerobius** Krönig *emend.* Natvig. (Krönig, Zent. f. Gyn., 1895; Natvig, Arch. f. Gyn., 1905, 76.) From Greek *an*, without; *aër*, air; *bios*, life; M. L., anaerobic.

Heurlin (Bakt. Unters. d. Keimgehaltses im Genitalkanale d. fiebernden Wöchnerinnen. Helsingfors, 1910, 122–127) recognizes the following varieties of *Streptococcus anaerobius*: *S. anaerobius vulgaris*, *S. anaerobius* typ. *vulgaris*, *S. anaerobius gonoides*, *S. anaerobius* (Wegelius No. 28), *S. anaerobius micros* (Lewkowicz), and *S. anaerobius carduus*.

Description according to Prévot, Ann. Sci. Nat., Sér. Bot., *15*, 1933, 180.

Spheres: Average size 0.8 micron, occurring in chains. Non-motile. Gram-positive.

Gelatin: No liquefaction.

Semi-solid agar (Veillon): After 48 hours colonies 1 to 2 mm in diameter, very regular, lenticular. Gas produced. Agar slightly acidified.

Martin broth: Rapid growth. No turbidity. Sediment in 24 hours. Medium slightly acidified. Feeble production of gas. Slight fetid odor.

Martin glucose broth: Very abundant growth. Gas fetid, inflammable, no H_2S. Very marked acidification.

Peptone water: Abundant flocculent growth. Gas produced at expense of peptone. Medium not acidified. Neither indole nor H_2S produced.

Meat and liver broth: Very abundant growth. Much gas produced which contains CO_2 and H_2.

Milk: No acid. No coagulation.

Cooked protein (egg white, meat, liver, fibrin and serum) not attacked. Fresh fibrin and fresh organs partially disintegrated with blackening, abundant gas, very fetid odor due in part to H_2S.

Serum broth: Abundant gas and fetid odor.

Neutral red broth: Changed to fluorescent yellow.

Acid from glucose, fructose, galactose, sucrose and maltose. Mannitol and arabinose sometimes fermented.

Optimum pH 6.0 to 8.0.

Temperature relations: Optimum 36° to 38°C. Grows at 26°C, but not below 22°C. Survives 5 minutes at 60°C or two minutes at 80°C. Killed in ten minutes at 80°C.

Pathogenic.

Strict anaerobe.

Distinctive characters: Very peptolytic; gas produced in peptone water with destruction of the peptone. Differs from

* See footnotes, p. 308. Reviewed by Dr. Ivan C. Hall.

Streptococcus foetidus by being morphologically like a typical streptococcus. Differs from *Streptococcus putridus* by its physiology, bread crumb-like growth, and the production of gas in all media.

Source: Isolated in cases of putrefactive gangrene; war wounds; uterus, lochia and blood in puerperal infections; appendicitis; pleurisy; and amniotic fluid.

Habitat: Mouth and intestines. Cavities of man and animals, especially the vagina. Can invade all tissues.

18. **Streptococcus foetidus** (Veillon) Prévot. (*Micrococcus foetidus* Veillon, Compt. rend. Soc. Biol. Paris, *45*, 1893, 867; not *Streptococcus foetidus* Migula, Syst. d. Bakt., *2*, 1900, 38; Prévot, Ann. Sci. Nat., Sér. Bot., *15*, 1933, 189.) From Latin *foetidus* (better *fetidus*), stinking.

Large spheres: 0.8 to 1.0 micron, occurring normally in short chains, also in tetrads, double or zig-zag chains. Non-motile. Gram-positive.

Gelatin: No liquefaction.

Semi-solid agar (Veillon): Slow growth. At first punctiform; small colonies ¼ to ½ mm in diameter, growing 1 to 2 cm below the surface, regular, thick, lenticular, opaque. Gas bubbles produced.

Blood agar: Small brownish hemopeptic zone around the colonies. No true hemolysis.

Martin broth: Poor growth. No turbidity. Flakes form on wall of tube, but rapidly settle to the bottom. Little or no gas. Very faint fetid odor.

Martin glucose broth: Good growth. No turbidity. Gas fetid, inflammable.

Meat and liver broth: Rapid, abundant growth. Abundant gas. Strong fetid odor.

Milk: No acid. No coagulation.

Peptone water: Gas production feeble. Indole not formed.

Neutral red broth changed to fluorescent yellow.

Fresh organs become green, then blacken. Much gas produced containing H_2S, later the organs are gradually disintegrated; partial bioproteolysis and H_2S fermentation.

Cooked protein not attacked.

Acid and gas from glucose, fructose, galactose and sucrose. No acid from lactose, maltose, arabinose, glycerol, mannitol, dulcitol or starch.

Temperature relations: Optimum 36° to 38°C. Feeble growth at 26°C. No growth below 22°C. Killed in one hour at 60°C or in ten minutes at 80°C.

Optimum pH 6.5 to 8.0.

Pathogenic for guinea pigs and mice.

Strict anaerobe.

Common in fetid suppurations and autogenous gangrenous processes.

Source: First isolated from a fatal case of Ludwig's angina. Perinephritic phlegmon; the fetid pus from Bartholin's gland; gangrene of the lung; appendicitis.

Habitat: Mouth, intestine and vagina of man and animals.

18a. *Streptococcus foetidus* var. *buccalis* Prévot. (Einen Micrococcus der Mundhöhle, Ozaki, Cent. f. Bakt., I Abt., Orig., *76*, 1915, 118; *Micrococcus buccalis* Bergey et al., Manual, 1st ed., 1923, 69; Prévot, Ann. Sci. Nat., Sér. Bot., *15*, 1933, 193.) From mouth.

19. **Streptococcus putridus** Schottmüller *emend.* Prévot. (Schottmüller, Mitteil. a. d. Grenzgeb. d. Med. Chirurg., *21*, 1910, 450; Prévot, Ann. Sci. Nat., Sér. Bot., *15*, 1933, 170, 184.) From Latin *putridus*, rotten, decayed.

Synonym: *Streptococcus putrificus* Schottmüller, Münch. med. Wochnschr., *68*, 1921, 662.

Spheres: Average size 0.8 micron, occurring in chains. Gram-positive.

Gelatin: No liquefaction.

Semi-solid agar (Veillon): More or less lenticular; colonies 1 to 2 mm in diameter. No gas produced.

Blood agar: A blackish-brown hemopeptic zone is produced around the colonies, with fetid gas (H_2S). Colonies become brownish, sometimes blackish.

Martin broth: In 6 to 8 hours uniform

turbidity which does not precipitate completely. No gas. Little odor.

Martin glucose broth: Rapid abundant growth. Uniform turbidity. Sediment. No gas. Slight fetid odor. Black pigment in the sediment.

Meat and liver broth: Very abundant growth, very marked putrid odor. Incomplete sedimentation.

Peptone water: Sparse growth. Neither gas, odor, H_2S nor indole.

Milk: No acid. No coagulation.

Cooked protein not attacked.

Deep blood agar: Agar is broken by the gas (H_2S).

Fresh blood broth: Abundant gas which contains a large amount of H_2S. Blood blackens rapidly, has typical putrid odor.

Fresh fibrin broth: The fibrin is broken up and partially digested.

Neutral red changed to fluorescent yellow.

Lead media blackened.

Acid from glucose, fructose and maltose. Acid sometimes produced from sucrose, mannitol and galactose.

Optimum pH 7.0 to 8.5.

Temperature relations: Optimum 36° to 38°C. Growth feeble at 28°C. No growth below 22°C. Killed in ten minutes at 80°C.

Pathogenic when grown in media with fresh tissue and body fluids.

Strict anaerobe.

Distinctive characters: Putrescence but absence of gas in ordinary media; presence of gas and H_2S in media with fresh tissue or body fluids.

Source: Normal and fetid lochia, blood in puerperal fever, gangrenous appendicitis, gangrene of the lung, in gas gangrene, gangrenous metastases; war wounds; osteomyelitis; and from amniotic fluid. Found in sea water by Montel and Mousseron (Paris Médical, 1929).

Habitat: Human mouth and intestine and especially the vagina.

20. Streptococcus lanceolatus Prévot. (*Coccus lanceolatus anaerobius* Tissier, Compt. rend. Soc. Biol. Paris, *94*, 1926, 447; Prévot, Ann. Sci. Nat., Sér. Bot., *15*, 1933, 173 and 193; not *Streptococcus lanceolatus pasteuri* nor *Streptococcus lanceolatus* Gamaleïa, Ann. Inst. Past., *2*, 1888, 440; not *Streptococcus lanceolatus* Saito, Arch. f. Hyg., *75*, 1912, 121.) Although Prévot's name is invalid, it is used until further comparative studies have been made. From Latin *lanceolatus*, having a little lance, pointed.

Large ovoid cells: 1.2 to 1.4 microns with pointed ends, occurring in short chains in culture and in pairs in exudates. Non-motile. Gram-positive.

Gelatin: No liquefaction.

Deep agar colonies: Very large, lenticular. Abundant gas produced which breaks up the medium.

Peptone broth: Uniform turbidity. Granular, glairy sediment.

Peptone water: Good growth. Gas produced.

Milk: No change.

Protein not attacked.

Hydrolyzed albumen reduced to CO_2, $(NH_4)_2CO_3$ and NH_3.

Acid from sucrose, glucose and starch. No acid from lactose. (Butyric, valerianic and acetic acid are produced, in the proportions 2:1:trace, from glucose and sucrose.)

Non-pathogenic for laboratory animals.

Optimum temperature 37°C.

Strict anaerobe.

Distinctive characters: Proteolytic and saccharolytic; produces ammonia from hydrolyzed proteins; butyric, valerianic and acetic acid produced from hexoses. No H_2S produced.

Source: From human feces in a case of diarrhoea.

Habitat: Putrefying materials.

21. Streptococcus micros Prévot. (*Streptococcus anaerobius micros* Lewkowicz, Arch. Méd. Exp., *13*, 1901, 645; Prévot, Ann. Sci. Nat., Sér. Bot., *15*, 1933, 193; also see Weiss and Mercado, Jour. Inf. Dis., *62*, 1938, 181.) From Greek *micrus*, small (old spelling, *micros*).

Very small spheres: 0.2 to 0.4 micron, occurring in long chains or in pairs. Non-motile. Gram-positive.

Gelatin: Poor growth. No liquefaction.

Semi-solid agar (Veillon): Slow growth; colonies at first punctiform, becoming lenticular and later forming processes into the medium. Average size 0.5 to 1.0 mm in diameter, some reach 2 to 3 mm growing 2 or 3 cm below the surface.

Blood agar: No hemolysis. No hemopeptolysis.

Martin broth: Slight particulate turbidity which slowly settles.

Meat and liver broth: Rapid growth. Abundant sediment.

Peptone water: Powdery sediment. Medium not acidified. No indole formed.

Neutral red broth: Changed to fluorescent yellow.

Milk: Grows with difficulty. No acid. No coagulation.

Acid produced rapidly from glucose, fructose, galactose, sucrose and maltose. No acid from lactose, arabinose, glycerol, mannitol, inulin and starch.

Protein not attacked.

Optimum pH about 7.0.

Optimum temperature 36° to 38°C. No growth at 22°C. Killed in a quarter of an hour at 60°C.

Non-pathogenic for mice.

No toxin and no hemolysin.

Strict anaerobe.

Distinctive characters: Neither gas nor fetid odor produced. Small size.

Source: Gangrene of the lung; lochia and uterus in puerperal sepsis; appendicitis.

Habitat: Mouth and intestine of man and animals.

22. **Streptococcus parvulus** Weinberg, Nativelle and Prévot. (*Streptococcus parvulus non liquefaciens* Repaci, Compt. rend. Soc. Biol., Paris, *68*, 1910, 528; Weinberg, Nativelle and Prévot, Les Microbes Anaérobies, 1937, 1011; not *Streptococcus parvulus* Levinthal, Cent. f. Bakt., I Abt., Orig., *106*, 1928, 195.) From Latin *parvulus*, very small, minute.

Small spheres: Average size 0.3 to 0.4 micron, occurring in short chains, sometimes in pairs. Non-motile. Gram-positive.

Gelatin: At 37°C slow growth, culture at bottom of the tube; no gas. No liquefaction.

Deep glucose agar colonies: After 48 hours very tiny, lenticular, whitish. Old colonies become blackened. No gas produced.

Broth: Rapid turbidity. Sediment forms in 5 or 6 days as a whitish, mucous mass which clears the fluid. No gas. Faint disagreeable odor.

Indole not formed.

Milk: Coagulation in 24 hours.

Egg white not attacked.

Feebly attacks glucose and lactose. Does not attack sucrose, galactose and dextrin.

Optimum temperature 37°C. No growth at room temperature. Will grow at 41°C.

Strict anaerobe.

Distinctive characters: Differs from *Streptococcus micros* by its black colonies, coagulation of milk and its feeble saccharolytic power. Differs from *Streptococcus intermedius* by its black colonies, the smallness of its elements, feeble saccharolytic power and the viscous sediment in broth.

Source: Respiratory tract.

Habitat: Unknown.

Veillon and Repaci identified this organism as *Streptococcus micros*, but Weinberg, Nativelle and Prévot consider it as a distinct species, although rare.

23. **Streptococcus intermedius** Prévot. (Ann. Inst. Past., *39*, 1925, 439.) From Latin *intermedius*, intermediate.

Description taken in part from Prévot, Ann. Sci. Nat., Sér. Bot., *15*, 1933, 197.

Spheres: 0.5 to 0.7 micron, very long chains in culture. Non-motile. Gram-positive.

Gelatin: Poor growth. No liquefaction.

Semi-solid agar (Veillon): After 24 hours colonies 1 to 2 mm in diameter, regular, lenticular; sometimes with complex processes.

Blood agar: No change or slight greening.

Martin broth: Rapid growth. Uniform turbidity which slowly settles.

Martin glucose broth: Abundant growth. Abundant sediment. Medium strongly acidified.

Peptone water: Particulate sediment.

Milk: Very acid. Coagulated in 24 hours, without retraction of clot and not peptonized.

Serum broth (1:2): Rapid growth. Coagulation by acidification.

Proteins not attacked.

Neutral red broth: Changed to fluorescent yellow.

Acid from glucose, fructose, galactose, maltose and lactose. Acid from sucrose by some strains. The acid produced is lactic acid. No acid from arabinose, glycerol, mannitol, dulcitol, inulin or starch.

Optimum pH 6.0 to 8.5.

Temperature relations: Optimum 36° to 38°C. Poor growth at 26°C. No growth below 22°C. Killed in half an-hour at 70°C or in ten minutes at 80°C.

Pathogenic for guinea pigs and mice, causing small abscesses; sometimes kills in 48 hours.

No toxin and no hemolysin.

Strict anaerobe.

Distinctive characters: Strongly acidifies media. Coagulates milk.

Source: Lochia and uterus in puerperal sepsis; gangrene of the lung; pleurisy; bronchiectasis; appendicitis.

Habitat: Human respiratory and digestive tracts and vagina.

24. Streptococcus evolutus Prévot. (*Streptococcus Sch.*, Gräf and Wittneben, Cent. f. Bakt., I Abt., Orig., *39*, 1925, 443; *Streptococcus Schwarzenbeck*, Ford, Textb. of Bact., 1927, 455; also see Weiss and Mercado, Jour. Inf. Dis., *62*, 1938, 181.) From Latin *evolutus*, unrolled.

Description taken in part from Prévot, Ann. Sci. Nat., Sér. Bot., *15*, 1933, 199.

Spheres: 0.7 to 1.0 micron, average 0.7 micron, occurring in pairs or in short and long chains. Pleomorphic. Often appear as short ovoid rods with rounded ends. Gram-positive.

Gelatin: Liquefaction.

Deep agar colonies: Lenticular or rosettes. Growth occurs about 1 cm beneath the surface; after a transfer the second generation may show a ring of growth in the middle of this sterile zone. This is the characteristic alternate zones appearance. Colonies usually become brownish with age.

Glucose broth: Abundant growth, resembling bread crumbs. Medium strongly acidified (pH 5). A small quantity of lactic acid produced.

Peptone broth: Rapid growth. No general turbidity. Precipitating flocculent growth on the wall of the tube.

Blood agar: No change, sometimes greening.

Peptone water: Flocculent growth. No turbidity. Indole not formed.

Litmus milk: Acid. Curdled in 24 hours, clot retracts and fragments. Slight peptonization with some strains.

Strongly acid in glucose, fructose, galactose, sucrose, lactose and maltose. Arabinose sometimes fermented.

Egg white not attacked.

Pathogenicity: Most strains not pathogenic, some produce slight local swelling subcutaneously with little pus in guinea pigs and mice.

Optimum pH 6.0 to 8.5.

Optimum temperature 36° to 38°C. No growth below 22°C.

Strict anaerobe at first, becoming facultative with subsequent transfers.

Viability short aerobically and several months anaerobically.

Distinctive characters: Growth in al-

ternate zones in agar. Strict anaerobe at first, later microaerophilic.

Source: Skin abscess; appendicitis.

Habitat: Respiratory tract, mouth, vagina.

Appendix I: Descriptions of poorly defined species, the taxonomic relationships of which are not clear.

1. **Streptococcus sp.** Long and Bliss. (Minute beta hemolytic streptococcus, Long and Bliss, Jour. Exp. Med., *60*, 1934, 619; Long, Bliss and Walcott, *ibid.*, 633.)

Minute cocci, half to two-thirds the size of *Streptococcus pyogenes*; occurring singly, in pairs, short chains and in small and large masses. Gram-positive, but may decolorize readily.

Blood agar: Very minute colonies 18 to 30 microns, surrounded by a marked area of hemolysis (beta), easily visible before the colony is seen by naked eye, 4 to 10 times the diameter of the colony. Under the microscope colonies are finely granular, may appear wrinkled and crenated. Colonies become visible after 48 to 96 hours incubation and relative area of hemolysis is 3 to 4 times diameter of colony.

Gelatin: Not liquefied.

Glucose broth: Growth diffuse, abundant.

Litmus milk: Not curdled; litmus not reduced.

Acid from glucose, maltose and sucrose; may or may not attack lactose, trehalose and salicin. No acid from arabinose, raffinose, inulin, glycerol, mannitol or sorbitol.

Does not hydrolyze sodium hippurate and starch. Esculin is hydrolyzed.

Ammonia is produced from peptone.

Temperature relations: No growth at 10°C, very rarely growth at 45°C. Does not survive 60°C for 30 minutes.

Chemical tolerance: Does not tolerate 6.5 per cent NaCl. Final pH in glucose broth 5.4 to 4.6; no growth at pH 9.6. Methylene blue 0.1 per cent not tolerated. No growth on 40 per cent bile-blood agar.

Action on blood: Hemolysis marked before colony is visible. May not produce soluble hemolysin by ordinary methods but does so abundantly by appropriate methods.

Fibrinolysin: No solution of human fibrin.

Serology: Constitutes Group F of Lancefield and Hare (Jour. Exp. Med., *61*, 1935, 335). Four serological types within the group (Bliss, Jour. Bact., *33*, 1937, 625).

Aerobe, facultative anaerobe.

Source: Human throat in health and disease, accessory sinuses, abscesses, vagina, skin and feces.

Habitat: Human upper respiratory tract.

2. **Streptococcus sp.** Long and Bliss. (Group II, Long and Bliss, Jour. Exp. Med., *60*, 1934, 633; Group G, Lancefield and Hare, Jour. Exp. Med., *61*, 1935, 346; Bliss, Jour. Bact., *33*, 1937, 625.)

Probably identical with *Streptococcus anginosus* Andrewes and Horder (Lancet, *2*, 1906, 712) but probably other serological types are included in this group (Sherman, Bacteriological Reviews, *1*, 1937, 40).

Spheres: Gram-positive.

Gelatin: Not liquefied.

Litmus milk: Acid, may be curdled, not reduced.

Acid from glucose, maltose, sucrose, trehalose and salicin; usually acid from lactose, and may or may not from raffinose and glycerol. No acid from arabinose, inulin, mannitol or sorbitol.

Sodium hippurate usually not hydrolyzed. May hydrolyze starch and esculin.

Ammonia is produced from peptone.

Temperature relations: No growth at 10°C and usually not at 45°C. Does not survive 60°C for 30 minutes.

Chemical tolerance: Does not tolerate 6.5 per cent NaCl. Final pH in glucose broth 6.0 to 4.6; no growth at pH 9.6. Methylene blue 0.1 per cent not tol-

erated. May grow on 40 per cent bile-blood agar, growth in 10 per cent bile.

Action on blood: Hemolytic (beta) with a wider zone than minute beta hemolytic streptococcus. Soluble hemolysin formed.

Fibrinolysis: May dissolve human fibrin, certain strains strongly, others weakly.

Serology: Constitutes Lancefield's and Hare's Group G. Bliss (*loc. cit.*) has shown serological Types I and II within the group. May include serological Type 16 of Griffith (Jour. Hyg., *34*, 1934, 542). Those resembling *Streptococcus anginosus* seem to form a homogeneous type; others seem unrelated to it.

Aerobic, facultative anaerobe.

Source: Human nose, throat, vagina, skin and feces in health. In human disease in puerperal fever with staphylococcus. Throat of normal domestic animals and in animal infections probably as secondary invaders.

Habitat: Human upper respiratory tract and vagina. Possibly throat of domestic animals.

3. **Streptococcus sp.** Brown, Frost and Shaw. (Jour. Inf. Dis., *38*, 1926, 381; Lancefield, Jour. Exp. Med., *57*, 1933, 571.)

Belongs to Lancefield Group E.

Gelatin: Not liquefied.

Litmus milk: Not curdled and not reduced.

Acid from glucose, lactose, trehalose and sorbitol; may form acid from sucrose, glycerol, mannitol and salicin. No acid from arabinose, raffinose or inulin.

No hydrolysis of sodium hippurate; may hydrolyze starch and esculin.

Ammonia is produced from peptone.

Temperature relations: No growth at 10°C and 45°C. Does not survive 60°C for 30 minutes.

Chemical tolerance: Does not tolerate 6.5 per cent NaCl. Final pH in glucose broth 4.8 to 4.2; no growth at pH 9.6. Methylene blue 0.1 per cent not tolerated and not reduced. No growth on 40 per cent bile-blood agar, nor on 10 per cent bile.

Action on blood: Very hemolytic; strains reported by Plastridge and Hartsell (Jour. Inf. Dis., *61*, 1937, 110) weakly hemolytic. Streptolysin produced and outstandingly acid stable (Todd, Jour. Path. and Bact., *39*, 1934, 299).

Fibrinolysin: No solution of human fibrin.

Serology: Lancefield Group E, some cross reaction with Group C.

Aerobe, facultative anaerobe.

Source: Certified milk; bovine udder.

Habitat: Probably in udder and dairy products.

4. **Streptococcus sp.** Hare. (Group H, Hare, Jour. Path. and Bact., *41*, 1935, 499.)

Spheres: Gram-positive.

Blood agar: Small colonies, 0.7 to 0.9 mm, smooth surface, greenish color tending to blacken, hard, almost gritty and adherent to the medium. Hemolysis seldom complete except on Brown's horse blood agar. On boiled blood agar definite greening and so different from Groups E, F and K.

Litmus milk: Not curdled and not reduced.

Acid from glucose, maltose, sucrose, raffinose and salicin; acid may be formed from lactose and trehalose. No acid from arabinose, inulin, glycerol, mannitol or sorbitol.

No hydrolysis of sodium hippurate and starch, but may hydrolyze esculin.

Ammonia may or may not be produced from peptone.

Temperature relations: No growth at 10°C. Growth at 45°C. May survive 60°C for 30 minutes.

Chemical tolerance: Does not tolerate 6.5 per cent NaCl. Final pH in glucose broth 5.0 to 4.5; no growth at pH 9.6. Methylene blue 0.1 per cent not tolerated. No growth on 40 per cent bile-blood agar.

Action on blood: Hemolysis incomplete

and some greening. No soluble hemolysin.

Fibrinolysin: No solution of human fibrin.

Serology: Group H.

Aerobe, facultative anaerobe.

Source: Human throat and feces.

Habitat: Human throat.

5. **Streptococcus sp.** Hare. (Group K, Hare, Jour. Path. and Bact., *41*, 1935, 499.)

Spheres: Gram-positive.

Blood agar: Colonies 0.8 to 1.3 mm, moist and transparent, with crenated edges. Incomplete hemolysis and no alpha-prime appearance.

Acid from glucose, lactose and salicin; may form acid from trehalose (doubtful). No acid from mannitol or sorbitol.

Does not hydrolyze sodium hippurate.

Chemical tolerance: Final pH in glucose broth 5.1 to 5.4. Does not grow on 10 per cent and 40 per cent bile-blood agar.

Action on blood: Incomplete hemolysis; does not produce soluble hemolysin. Doubtful if truly hemolytic streptococcus.

Fibrinolysin: Does not dissolve human fibrin.

Serology: Group K.

Aerobe, facultative anaerobe.

Source: Human throat.

Habitat: Human throat. No indication of relation to disease.

6. **Streptococcus acidominimus** Ayers and Mudge. (Ayers and Mudge, Jour. Inf. Dis., *31*, 1922, 40; *33*, 1923, 155.) From M. L., derived to mean a minimum amount of acid.

Description taken from Smith and Sherman, Jour. Inf. Dis., *65*, 1939, 301.

Spheres: Generally occur in short chains. Gram-positive.

Gelatin stab: Filiform, beaded growth. No liquefaction.

Plain nutrient agar: Small round white colonies.

Acid from glucose, lactose and sucrose. May form acid from maltose, trehalose, and mannitol. Sorbitol and salicin usually are not fermented. No acid from arabinose, xylose, raffinose, inulin and glycerol.

Sodium hippurate is hydrolyzed but not starch.

Carbon dioxide is produced from a 4 per cent peptone-infusion broth.

Litmus milk: Little or no visible change.

Ammonia is not produced from peptone.

Temperature relations: No growth at 10°C. A few cultures grow at 45°C. Do not survive 60°C for 30 minutes.

Chemical tolerance: No growth in .01 per cent methylene blue. Growth in 2 per cent but not in 6.5 per cent NaCl. Final pH in glucose broth 6.5 to 5.6. No growth at pH 9.6.

Action on blood: No hemolysis, slight greening (alpha).

Serology: Negative reaction with serums representing Lancefield groups A, B, C, D, E, F and G.

Facultative anaerobe.

Distinctive character: Small amount of acidity developed in fermentation tests.

Source: Originally 12 cultures were isolated from freshly drawn milk. Also found in bovine vagina, occasionally in the udder, and on the skin of calves.

Habitat: Known to occur abundantly in the bovine vagina.

The relationship between *Streptococcus uberis* Diernhofer and other similar streptococci is not yet entirely clear. Smith and Sherman (Jour. Inf. Dis., *65*, 1939, 301–305) at one time thought that *Streptococcus uberis* and *Streptococcus acidominimus* might be identical. Others have regarded *Streptococcus uberis* as identical with Group III, Minett (Proc. 12th Internat. Vet. Cong., *2*, 1934, 511).

Brown (Proc. 3rd Internat. Cong. for Microbiol., 1940, 173) describes a new species, *Streptococcus lentus* (not *Strep-*

tococcus lentus Lehmann, Deutsch. Arch. f. klin. Med., *150*, 1926, 144) which belongs to serological group E. He states that a few strains that produced the alpha appearance in blood agar corresponded culturally with *Streptococcus uberis*.

Later Sherman (personal communication) had an opportunity to determine the serological group of several cultures of *Streptococcus uberis* carefully identified by R. B. Little and found them to belong to Group D. While their characters were not exactly the same as the conventional *Streptococcus faecalis*, he feels that these cultures of *Streptococcus uberis* were only a variant type of *Streptococcus faecalis*.

Appendix II.* The following species of streptococci are listed chiefly because of their historical interest. In many cases the original cultures are lost and their exact taxonomic relationships have not been determined.

Bacterium acetylcholini Habs. (Cent. f. Bakt., II Abt., *97*, 1937, 194.) From ensilage. Regarded as a stable type of *Enterococcus*.

Diplococcus bombycis Paillot. (Annales des Épiphyties, *8*, 1922, 131.) From the silkworm (*Bombyx mori*).

Diplococcus liparis Paillot. (Annales des Épiphyties, *8*, 1922, 122.) From larvae of the gypsy moth (*Porthetria (Lymantria) dispar*).

Diplococcus lymantriae Paillot. (Compt. rend. Acad. Sci., Paris, *164*, 1917, 526.) From larvae of the gypsy moth (*Porthetria (Lymantria) dispar*).

Diplococcus melolonthae Paillot. (Compt. rend. Soc. Biol., Paris, *69*, 1917, 57; Annales des Épiphyties, *8*, 1922, 118.) From diseased larvae of cockchafers (*Melolontha melolontha*).

Diplococcus pieris Paillot. (Annales des Épiphytes, *8*, 1922, 128.) From diseased caterpillars of the cabbage butterfly (*Pieris brassicae*).

Diplococcus scarlatinae sanguinis Jamieson and Edington. (Brit. Med. Jour., *1*, 1887, 1265.) From the desquamation and blood of scarlet fever patients.

Enterococcus citreus Stutzer and Wsorow. (Cent. f. Bakt., II Abt., *71*, 1927, 117.) From normal pupae of a moth (*Euxoa segetum*).

Lactococcus agglutinans Plevako and Bakushinskaia. (Microbiology (Russian), *4*, 1935, 523; abst. in Cent. f. Bakt., II Abt., *94*, 1936, 64.) Agglutinates baker's yeast.

Streptobacillus malae Goadby. (Jour. State Med. London, *30*, 1922, 417; *Streptococcus malae* Thomson and Thomson, Ann. Pickett-Thomson Res. Lab., *5*, 1929, 22.) From the mouth. An aberrant streptococcus.

Streptococcus abortus-equi Hauduroy et al. (*Streptococcus abortus equi* Ostertag, Monatsh. f. Tierheilk., *12*, 1900, 384; Hauduroy et al., Dict. d. Bact. Path., Paris, 1937, 508.) From aborting mares.

Streptococcus acidi-lactici Chester. (*Sphaerococcus acidi lactici* Marpmann, Ergänzungshefte d. allegemeine Gesundheitspflege, *2*, 1886, 121; not *Streptococcus acidi lactici* Grotenfeldt, Fortschr. d. Med., *7*, 1889, 124; *Micrococcus lacticus* Migula, Syst. d. Bakt., *2*, 1900, 66; Chester, Man. Determ. Bact., 1901, 65.) From fresh milk.

Streptococcus aerobius Heurlin. (Bakt. Untersuch. d. Keimgehaltes im Genitalkanale der fiebernden Wöchnerinnen, Helsingfors, 1910, 60.) From the genital canal.

Streptococcus aerogenes Wirth. (Cent. f. Bakt., I Abt., Orig., *99*, 1926, 290.) From human blood. An aerobic species which produced gas in deep glucose agar.

Streptococcus aerophilus Trevisan. (I generi e le specie delle Batteriacee, Milan, 1889, 31; not *Streptococcus aerophilus* Heurlin, Bakt. Untersuch. d. Keimgehaltes im Genitalkanale der fiebernden Wöchnerinnen, Helsingfors, 1910, 62.) From air.

* Prepared by Miss Eleanore Heist, July, 1938; revised by Prof. Robert S. Breed, New York State Experiment Station, Geneva, New York, February, 1944.

Streptococcus alactosus Smith and Brown. (Jour. Med. Res., *31*, 1915, 455; Rockefeller Inst. for Med. Res., Monograph 9, 1919; *Streptococcus haemolyticus II*, Holman, Jour. Med. Res., *34*, 1916, 377.) From human tonsillitis; peritoneal pus. See Manual, 5th ed., 1939, 352 for description of this species.

Streptococcus albicans Migula. (Schminkeweisser Streptococcus, Tataroff, Inaug. Diss., Dorpat, 1891, 69; Migula, Syst. d. Bakt., *2*, 1900, 22.) From water.

Streptococcus albidus Henrici. (Arb. bakt. Inst. Karlsruhe, *1*, Heft 1, 1894, 53.) From Cantal cheese.

Streptococcus albus Sternberg. (Weisser Streptococcus, Maschek, Bakt. Untersuch. d. Leitmeritzer Trinkwasser, Jahresber. d. Oberrealschule zu Leitmeritz, 1887; Sternberg, Man. of Bact., 1893, 610; *Micrococcus albus* Macé, Traité pratique de Bact., 6th ed., 1912, 605.) From water.

Streptococcus allantoicus Barker. (Jour. Bact., *40*, 1943, 251.) From black mud, San Francisco Bay.

Streptococcus alvearis (Preuss) Trevisan. (*Cryptococcus alvearis* Preuss, 1868; Trevisan, I generi e le specie delle Batteriacee, 1889, 31.) From an infection (foulbrood?) in bees.

Streptococcus ambratus Trevisan. (Micrococco ambrato, Perroncito and Ajroldi, Giornale d. r. Accad. d. Med. d. Torino, *48*, 1885, 809; Trevisan, I generi e le specie delle Batteriacee, 1889, 30.) From the respiratory tract of a horse.

Streptococcus anhaemolyticus Rolly. (*Streptococcus anhaemolyticus vulgaris* Zangemeister, Münch. med. Wochnschr., *57*, 1910, 1268; Rolly, Cent. f. Bakt., I Abt., Orig., *61*, 1912, 90.) Synonym of *Streptococcus saprophyticus* Mandelbaum (Ztschr. f. Hyg., *58*, 1907, 37; see Brown, Monograph No. 9, Rockefeller Inst. Med. Res., 1919, 87). From vaginal secretions, milk and saliva.

Streptococcus aphthicola Trevisan. (I generi e le specie delle Batteriacee, 1889, 30.) From the lesions of foot and mouth disease of cattle.

Streptococcus aromaticus van Beynum and Pette. (Directie Landbouw. Verslag. Landbouwk. Onderzoek., *42*, 1936, 360; also see Hoecker and Hammer, Iowa Agr. Exp. Sta. Res. Bull. 290, 1941, 317.) Produces diacetyl and small amounts of acetylmethylcarbinol in milk. From cream and butter.

Streptococcus articulorum Flügge. (Die Mikroorganismen, 2 Aufl., 1886, 153.) Associated with diphtheria. Trevisan (I generi e le specie delle Batteriacee, 1889, 30) considers this identical with *Streptococcus diphteriticus* Cohn (Beitr. z. Biol. d. Pflanz., *1*, Heft 2, 1872, 162).

Streptococcus asalignus Frost, Gumm and Thomas. (Jour. Inf. Dis., *40*, 1927, 703.) From milk.

Streptococcus aurantiacus Killian and Fehér. (Ann. Inst. Past., *55*, 1935, 619.) From Sahara Desert soil.

Streptococcus bombycis Sartirana and Paccanaro. (Cent. f. Bakt., I Abt., Orig., *40*, 1906, 331; probably not *Streptococcus bombycis* Zopf, Die Spaltpilze, 2 Aufl., 1884, 52.) From diseased silk worms (*Bombyx mori*). According to Paillot (Les maladies du ver à soie, Lyon, 1928, 171) this is the same as *Streptococcus pastorianus* Krassilstschik.

Streptococcus bonvicini Chester. (Streptococcus della leucaemia, Bonvicini, Cent. f. Bakt., I Abt., *21*, 1897, 211; Chester, Man. Determ. Bact., 1901, 59.) From a case of leucaemia in a dog.

Streptococcus bovinus Trevisan. (*Micrococcus bovinus* Trevisan, Rendiconti Reale Inst. Lombardo di Sci. e Lett., Ser. II, *12*, 1879; Trevisan, I generi e le specie delle Batteriacee, 1889, 30; not *Micrococcus bovinus* Migula, Syst. d. Bakt., *2*, 1900, 67; not *Streptococcus bovinus* Broadhurst, Jour. Inf. Dis., *17*, 1915, 321; not *Streptococcus bovinus* Frost and Engelbrecht, The Streptococci, 1940, 56.) From human throat; bovine, equine, feline and canine feces.

Streptococcus brevis von Lingelsheim.

(Ztschr. f. Hyg., *10*, 1891, 339 and 354.) Not pathogenic. From various human and animal sources.

Streptococcus brevis non hemolyticus Sachs. (Ztschr. f. Hyg., *63*, 1909, 466.) From tonsils, vagina and vulva.

Streptococcus brightii DeToni and Trevisan. (Streptococcus bei Morbus Brightii, Mannaberg, Cent. f. klin. Med., *9*, 1888, 537; DeToni and Trevisan, in Saccardo, Sylloge Fungorum, *8*, 1889, 1057; *Streptococcus morbi brightii* Migula, Syst. d. Bakt., *2*, 1900, 28.) From urine of persons suffering from Bright's disease. Probably identical with *Streptococcus pyogenes*.

Streptococcus buccalis Blake. (Jour. Med. Res., *36*, 1917, 124.) From the mouth. Proposed to include both *Streptococcus mitis* and *Streptococcus salivarius*.

Streptococcus butyricus (Fitz) DeToni and Trevisan. (*Micrococcus butyricus* Fitz, Ber. d. deutsch. chem. Gesellsch., Denaeyer Bact. schizom., p. 35; DeToni and Trevisan, in Saccardo, Sylloge Fungorum, *8*, 1889, 1064.) From bovine feces. Forms butyric acid from calcium lactate.

Streptococcus cadaveris Sternberg. (Man. of Bact., 1893, 611.) From liver of yellow fever cadaver.

Streptococcus caprinus Emoto. (Jour. Japan. Soc. Veter. Sci., *3*, 1924, 67.) From the cerebro-spinal fluid of goats. Pathogenic for goats.

Streptococcus capsulatus Hauduroy et al. (*Streptococcus capsulatus gallinarum* Dammann and Manegold, Deutsche tierärztl. Wochnschr., *13*, 1905, 577 and Arch. f. Tierheilk., *33*, 1907, 41; Hauduroy et al., Dict. d. Bact. Path., 1937, 511; not *Streptococcus capsulatus* Binaghi, Cent. f. Bakt., I Abt., *22*, 1897, 273.) Causes a disease of chickens.

Streptococcus carneus Migula. (*Micrococcus*?, List, Inaug. Diss., Leipzig, 1885, 49; Migula, Syst. d. Bakt., *2*, 1900, 36.) From the stomach of a sheep. Probably a micrococcus.

Streptococcus carnis Chester. (Diplococcus, Harrevelt, Cent. f. Bakt., I Abt., *26*, 1899, 121; Chester, Man. Determ. Bact., 1901, 60.) From meat.

Streptococcus carrosus Lindner. (50 Jubiläumsber. Westpreuss. Bot.-Zool. Vereins, Danzig, 1928, 254.) From Mexican pulque.

Streptococcus casei Burri. (Berichte d. Schweiz. Bot. Gesellsch., *51*, 1940, 102.) From Emmenthal cheese.

Streptococcus caucasicus Migula. (Streptococcus a, von Freudenreich, Cent. f. Bakt., II Abt., *3*, 1897, 87; Migula, Syst. d. Bakt., *2*, 1900, 42.) From kefir. Possibly related to *Streptococcus kefir*.

Streptococcus cerasinus (Lehmann and Neumann) Migula. (Micrococcus?, List, Inaug. Diss., Leipzig, 1885, 17; Kirschroter Micrococcus, Adametz, Mitteil. d. österreich. Versuchssta. f. Brauerei u. Mälzerei in Wien, Heft 1, 1888, 33; *Micrococcus cerasinus siccus* Eisenberg, Bakt. Diag., 3 Aufl., 1891, 34; *Micrococcus cerasinus* Lehmann and Neumann, Bakt. Diag., 1 Aufl., *2*, 1896, 179; Migula, Syst. d. Bakt., *2*, 1900, 35; not *Micrococcus cerasinus* Migula, *ibid.*, 170.) From nasal secretions in a sheep; also from water.

Streptococcus charrini Trevisan. (Microbe de la septicémie consécutive au charbon, Charrin, Compt. rend. Soc. Biol., Paris, *36*, 1884, 526; Streptococcus Charrin, Flügge, Die Mikroorganismen, 2 Aufl., 1886, 164; Trevisan, I generi e le specie delle Batteriacee, 1889, 30.) From the organs of a rabbit having anthrax.

Streptococcus cinereus Zimmermann. (Bakt. unserer Trink- u. Nutzwässer, Chemnitz, II Reihe, 1894, 64.) From water.

Streptococcus citreus (Eisenberg) Migula. (Micrococcus?, List, Inaug. Diss., Leipzig, 1885, 60; Crêmefarbiger Micrococcus, Adametz, Mitteil. d. österreich. Versuchssta. f. Brauerei u. Mälzerei in Wien, Heft 1, 1888, 31; *Micrococcus citreus* Eisenberg, Bakt. Diag., 3 Aufl., 1891, 36; Migula, Syst. d. Bakt., *2*, 1900, 37; not *Streptococcus citreus* Weiss, Arb. bakt. Inst. Karlsruhe, *2*, Heft 3, 1902, 179.)

From the pancreas of a sheep (List); from water (Adametz).

Streptococcus citrophilus van Beynum and Pette. (Directie Landbouw. Verslag. Landbouwk. Onderzoek., *42*, 1936, 360; also see Hoecker and Hammer, Iowa Agr. Exp. Sta. Res. Bull. 290, 1941, 317.) Produces diacetyl, acetylmethylcarbinol and volatile acids from citric acid. From cream and butter.

Streptococcus coli Migula. (*Streptococcus coli brevis* Escherich, Die Darmbakterien des Säuglings und ihre Beziehungen zur Physiologie der Verdauung, 1886, 86; Migula, Syst. d. Bakt., *2*, 1900, 33.) From stools in cases of infant diarrhoea.

Streptococcus continuosus Black. (Trans. Ill. State Dental Soc., *22*, 1886, 189.) From the mouth.

Streptococcus coronatus (Flügge) Trevisan. (*Micrococcus coronatus* Flügge, Die Mikroorganismen, 2 Aufl., 1886, 175; Trevisan, I generi e le specie delle Batteriacee, 1889, 31.) From the air.

Streptococcus cuniculi Bergey et al. (Manual, 1st ed., 1923, 50.) From natural infections of rabbits. Morphologically like *Streptococcus pyogenes*.

Streptococcus cystitidis Migula. (*Diplococcus ureae pyogenes* Rovsing, Die Blasenentzündungen, ihre Actiologie, Pathogenese und Behandlung, 1890, 39; Migula, Syst. d. Bakt., *2*, 1900, 12.) From a case of cystitis.

Streptococcus debilis Wilhelmy. (Arb. bakt. Inst. Karlsruhe, *3*, 1903, 13.) From meat extracts.

Streptococcus dentium (Trevisan) Trevisan. (*Micrococcus dentium* Trevican, Batt. Ital., 1879, 27; *Micrococcus foetidus* Flügge, Die Mikroorganismen, 2 Aufl., 1886, 172; Trevisan, I generi e le specie delle Batteriacee, 1889, 30.) From carious teeth. Grows anaerobically in nutrient agar with the production of gas and strong odor.

Streptococcus desidens Trevisan. (*Micrococcus flavus desidens* Flügge, Die Mikroorganismen, 2 Aufl., 1886, 177; Trevisan, I generi e le specie delle Batteriacee, 1889, 31; *Micrococcus desidens* Migula, Syst. d. Bakt., *2*, 1900, 143.) From the air.

Streptococcus diacetilactis Matuszewski, Pijanowski and Supinska. (Compt. rend. Inst. Bact. École Cent. Agron., Varsovie, Poland, No. 21, 1936, 1.) From milk. Probably *Streptococcus cremoris* Orla-Jensen.

Streptococcus diacetyl aromaticus. (Quoted from Karnad, Indian Jour. Vet. Sci., *9*, 1939, 349.) From milk. Produces an aroma in milk cultures.

Streptococcus disparis Glaser. (Jour. Agr. Res., *13*, 1918, 515.) From the alimentary canal of caterpillars.

Streptococcus endocarditicus DeToni and Trevisan. (Mikrokokken, Klebs, Arch. f. exper. Pathol., *9*, 1878, 52; DeToni and Trevisan, in Saccardo, Sylloge Fungorum, *8*, 1889, 1057.) From cases of endocarditis.

Streptococcus enteritidis Chester. (Enteritisstreptokokken, Escherich, Jahrb. f. Kinderheilk., *49*, 1899, 161; Chester, Man. Determ. Bact., 1901, 59.) From cases of enteritis.

Streptococcus enteritis Chester. (*Streptococcus*, Hirsh, Cent. f. Bakt., I Abt., *22*, 1897, 372 and Libman, *ibid.*, 376; Chester, Man. Determ. Bact., 1901, 56; *Streptococcus enteritis* var. *libmanii* Chester, *ibid.*, 66.) From stools in cases of infant diarrhoea.

Streptococcus equarius Frost and Engelbrecht. (A Revision of the Genus *Streptococcus*, privately published, 1936, 3 pp. and The Streptococci, 1940, 65.) From a throat culture.

Streptococcus equinus Lehmann and Neumann. (Streptokokken die sich zu grossen Konvaluten zusammenballen, Behring, Cent. f. Bakt., *12*, 1892, 194; Lehmann and Neumann, Bakt. Diag., 1 Aufl., *2*, 1896, 125.) From equine pneumonia. Relation to *Streptococcus equinus* Andrewes and Horder not clear.

Streptococcus felinus Bergey et al. (Manual, 1st ed., 1923, 50.) From natural infections in cats. Morphologically like *Streptococcus pyogenes*.

Streptococcus fermenti (Trevisan) Trevisan. (*Micrococcus fermenti* Trevisan, Batt. Ital., 1879, 19; *Micrococcus viscosus* Flügge, Die Mikroorganismen, 2 Aufl., 1886, 172; Trevisan, I generi e le specie delle Batteriacee, 1889, 31.) From a slimy growth in wines.

Streptococcus fischeli Chester. (Microorganismus No. 2, Fischel, Ztschr. f. Heilkunde, *12*, 1891, 7 and Cent. f. Bakt., *9*, 1891, 611; Chester, Man. Determ. Bact., 1901, 59.) From the blood of influenza patients.

Streptococcus foetidus Migula. (Stinkcoccus, Klamann, Allegem. med. Centralzeitung, 1887, 1347; *Diplococcus fluorescens foetidus* Eisenberg, Bakt. Diag., 1891, 10; Migula, Syst. d. Bakt., *2*, 1900, 38; *Streptococcus fluorescens* Chester, Man. Determ. Bact., 1901, 70; *Streptococcus fluorescens foetidus* Miquel and Cambier, Traité de Bact., Paris, 1902, 792.) From cases of ozena.

Streptococcus galleriae Chorine. (Compt. rend. Soc. Biol., Paris, *95*, 1926, 201.) From the bee moth (*Galleria mellonella*).

Streptococcus genitalium Dimock and Edwards. (Kentucky Agr. Exp. Sta. Res. Bull. 286, 1928, 162.) Found commonly in the genital tract of mares.

Streptococcus giganteus Migula. (*Streptococcus giganteus urethrae* Lustgarten and Mannaberg, Vierteljahrsschr. f. Dermatologie u. Syphilis, 1887, 918; Migula, Syst. d. Bakt., *2*, 1900, 39.) From human urethra and from urine.

Streptococcus gingivae. (Quoted from Annals Pickett-Thomson Res. Lab., *3*, 1927, 154.) From human gums and teeth.

Streptococcus granulatus Henrici. (Arb. bakt. Inst. Karlsruhe, *1*, Heft 1, 1894, 55.) From cream cheese.

Streptococcus haematosaprus Trevisan. (Mikrokokken der Fäulniss, Flügge, Die Mikroorganismen, 2 Aufl., 1886, 173; Trevisan, I generi e le specie delle Batteriacee, 1889, 31.) From putrefying blood.

Streptococcus halitus Heim and Schlirf. (Cent. f. Bakt., I Abt., Orig., *100*, 1926, 39.) From deposit on the tongue.

Streptococcus havaniensis Sternberg. (Man. of Bact., 1893, 612.) From acid vomit of a yellow-fever patient.

Streptococcus hemolyticus I, II and *III* Holman. (Jour. Med. Res., *34*, 1916, 388.) From various human infections.

Streptococcus herbarum Schieblich. (Cent. f. Bakt., I Abt., Orig., *124*, 1932, 269.) From green plant material. Motile. Related to *Streptococcus lactis* except it is flagellated. Kolbmuller (Cent. f. Bakt., I Abt., Orig., *133*, 1935, 310) identifies this with *Enterococcus*.

Streptococcus hydrophoborum Trevisan. (Streptococcus bei Rabies, Babes, Ztschr. f. Hyg., *5*, 1888, 184; Trevisan, I generi e le specie delle Batteriacee, 1889, 30.) From the brain in a case of rabies.

Streptococcus influentiae Trevisan. (I generi e le specie delle Batteriacee, 1889, 30.) From equine influenza.

Streptococcus influenzae Thomson and Thomson. (Grippestreptokokkus, Seligmann, Cent. f. Bakt., I Abt., Ref., *50*, 1911, 81; Thomson and Thomson, Monograph No. 16, Part I, Annals Pickett-Thomson Res. Lab., 1933.) Associated with influenza.

Streptococcus infrequens Holman. (Jour. Med. Res., *34*, 1916, 388.) From various human infections.

Streptococcus kirchneri Chester. (Diplococcus, Kirchner, Ztschr. f. Hyg., *9*, 1890, 528; Chester, Man. Determ. Bact., 1901, 57.) From sputum in cases of influenza.

Streptococcus kochii Trevisan. (I generi e le specie delle Batteriacee, 1889, 30.) From rabbit septicemia.

Streptococcus lacteus Schröter. (Kryptogam. Flora v. Schlesien, *3*, 1, 1886, 149.) From the air and dust.

Streptococcus lactis aromaticus Joshi and Ram Ayyar. (Indian Jour. Vet. Sci., *6*, 1936, 141.) Possibly *Streptococcus cremoris* Orla-Jensen. From cream.

Streptococcus lactis innocuus Stölting. (Inaug. Diss., Kiel, 1935, 16.) From ripening cheese.

Streptococcus lagerheimii var. *subterraneum* Migula. (Hansgirg, Oesterr. Zeitung, 1888, No. 7 and 8; Migula, Syst. d. Bakt., *2*, 1900, 41.) From the wall of a wine cellar.

Streptococcus (Diplococcus) lanceolatus ovium Gaertner. (Cent. f. Bakt., I Abt., Orig., *54*, 1910, 546.) From mastitis in sheep.

Streptococcus lapillus Heim and Schlirf. (Cent. f. Bakt., I Abt., Orig., *100*, 1926, 39.) From the oral cavity.

Streptococcus lentus Lehmann. (Lehmann, Deutsch. Arch. f. klin. Med., *150*, 1926, 144; *Streptococcus pyogenes lentus*, *ibid.*, 141; not *Streptococcus lentus* Brown, Rept. Proc. Third Internat. Congr. for Microbiol., New York, 1940, 173.) From urine, cervix, sputum and carious teeth.

Streptococcus libaviensis Flatzek. (Cent. f. Bakt., I Abt., Orig., *82*, 1919, 240; *Bacterium libaviense* Flatzek, *idem.*) From human feces. Motile.

Streptococcus lucae Trevisan. (*Micrococcus ulceris mollis* de Luca, 1886; Trevisan, I generi e le specie delle Batteriacee, 1889, 30.) From chancroidal ulcers.

Streptococcus luteus Killian and Fehér. (Ann. Inst. Past., *55*, 1935, 619.) From Sahara Desert soil.

Streptococcus magnus Henrici. (Arb. bakt. Inst. Karlsruhe, *1*, Heft 1, 1894, 54.) From Brie cheese.

Streptococcus malaperti Trevisan. (Micrococcus E, Malapert-Neuville, 1887; Trevisan, I generi e le specie delle Batteriacee, 1889, 30.) From mineral water of hot springs at Schlangenbad.

Streptococcus malignus Trevisan. (*Streptococcus pyogenes malignus* Flügge, Die Mikroorganismen, 2 Aufl., 1886, 153; Trevisan, I generi e le specie delle Batteriacee, 1889, 30.) From a diseased spleen. Probably identical with *Streptococcus pyogenes*.

Streptococcus mammitis bovis Hutchens. (Hutchens, in Besson, Pract. Bact. Microbiol. and Serum Therapy. Trans. of 5th ed., 1913, 613.) From mastitis in cattle.

Streptococcus margaritaceus Schröter. (In Cohn, Kryptog. Flora v. Schlesien, *3*, 1, 1886, 149.) From putrefying blood.

Streptococcus mathersi Muslow. (Green producing streptococcus, Tunnicliff, Jour. Amer. Med. Assoc., *71*, 1918, 1733; Mather's coccus, Jordan, Jour. Inf. Dis., *25*, 1919, 30; Muslow, *ibid.*, *31*, 1922, 295.) From sputum in cases of influenza and pneumonia.

Streptococcus maximus Weiss. (Arb. bakt. Inst. Karlsruhe, *2*, Heft 3, 1902, 180.) From a bean and carrot infusion.

Streptococcus melanogenes Schlegel. (Berl. tierarztl. Wochnschr., 1906, No. 25, 464.) Produces grayish-yellow pigment in gelatin. Associated with a disease of horses.

Streptococcus meningitidis Bonome. (Cent. f. Bakt., *8*, 1890, 172 and 703.) From exudates from cases of cerebrospinal meningitis.

Streptococcus merdarius Trevisan. (Streptococcus des selles, Cornil and Babes, Bactérica, 2nd ed., 1886, 118; Trevisan, I generi e le specie delle Batteriacee, 1889, 31.) From feces.

Streptococcus microapoikia Cooper, Keller and Johnson. (Amer. Jour. Dis. of Children, *47*, 1934, 388 and 596; these authors also use the trinomial *Streptococcus micro-apoikia enteritis*.) From human throat and feces in enteritis in children. See Manual, 5th ed., 1939, 351 for description of this species.

Streptococcus mirabilis Roscoe and Lunt. (Phil. Trans. Roy. Soc., London, *182*, 1892, 648.)

Streptococcus mixtus Bergey et al. (Manual, 1st ed., 1923, 49.) From a variety of pyogenic inflammations.

Streptococcus morbilli Ferry and Fisher. (Jour. Amer. Med. Assoc., *86*, 1926, 933.) From blood of persons in early stages of measles.

Streptococcus morbillosus Trevisan. (*Micrococcus morbillosus* Trevisan, Rendiconti Reale Inst. Lombardo di Sci. e Lett., Ser. II, *12*, 1879; Trevisan, I generi e le specie delle Batteriacee, 1889, 30.) From human, canine and porcine measles.

Streptococcus murisepticus v. Lingels-

heim. (Ztschr. f. Hyg., *10*, 1891, 331 and *12*, 1892, 308.) Migula (Syst. d. Bakt., *2*, 1900, 6) considers this a synonym of *Streptococcus pyogenes*.

Streptococcus mutans Clarke. (Brit. Jour. Exp. Path., *5*, 1924, 142.) Shows extreme variability in colony formation. Regarded as the cause of dental caries.

Streptococcus nasalis (Hack) Migula. (*Micrococcus nasalis* Hack, according to Eisenberg, Bakt. Diag., 3 Aufl., 1891, 55; Migula, Syst. d. Bakt., *2*, 1900, 45; *Planococcus nasalis* Migula, *loc. cit.*, 274.) From nasal secretions. Considered motile.

Streptococcus necroseos Schröter. (Mikrokokkus der progressiven Gewebenekrose bei Mäusen, Koch, Untersuch. über die Ätiologie der Wundinfektionskrankheiten. Leipzig, 1878 or Gesamm. Werke v. Robert Koch, *1*, 1912, 87; Schröter, in Cohn, Kryptog. Flora v. Schlesien, *3*, 1, 1886, 150; *Streptococcus necroticus* Trevisan, Atti della Accad. Fisio-Medico-Statistica in Milano, Ser. 4, *3*, 1885.) From gangrene in mice.

Streptococcus nomae Trevisan. (I generi e le specie delle Batteriacee, 1889, 30.) From gangrene of the mouth.

Streptococcus non-hemolyticus I, II and *III* Holman. (Jour. Med. Res., *34*, 1916, 388.) From various human and animal infections.

Streptococcus odontolyticus Belding and Belding. (Dental Items of Interest, *62*, 1940, 308.) From dental caries. Later stated by authors (Jour. Amer. Dent. Assoc., *30*, 1943, 713) to be a mucoid variant of *Streptococcus salivarius*.

Streptococcus opacus Heim and Schlirf. (Cent. f. Bakt., I Abt., Orig., *100*, 1926, 40.) From the oral cavity.

Streptococcus opportunus Brown. (Rept. Proc. Third Internat. Congr. for Microbiol., New York, 1940, 173.) Source not recorded. Belongs to Lancefield's Group B (Sherman, Chase and Niven, Jour. Bact., *41*, 1941, 101).

Streptococcus ovis Weimann. (Ztschr. f. Infectionskrankh. d. Haustiere, *9*, 1911, 255.) From infected sheep.

Streptococcus pallens Henrici. (Arb. bakt. Inst. Karlsruhe, *1*, Heft 1, 1894, 57.) From Gouda cheese.

Streptococcus pallidus Henrici. (Arb. bakt. Inst. Karlsruhe, *1*, Heft 1, 1894, 58.) From Neufchâtel cheese.

Streptococcus parvulus Levinthal. (Cent. f. Bakt., I Abt., Orig., *106*, 1928, 195.) From the mucous membrane of the human throat.

Streptococcus pastorianus Krassilstschik. (Compt. rend. Acad. Sci. Paris, *123*, 1896, 427.) From silkworms.

Streptococcus perniciosus Zopf. (Zopf, Die Spaltpilze, 3 Aufl., 1885, 53; *Streptococcus perniciosus psittacorum* Flügge, Die Mikroorganismen, 2 Aufl., 1886, 164; *Micrococcus perniciosus* Crookshank, Man. of Bact., 3rd ed., 1890, 252; *Streptococcus psittacorum* Migula, Syst. d. Bakt., *2*, 1900, 42.) From an infection of parrots. Found in nodules on the surface of the kidneys, lungs and spleen.

Streptococcus phytophthorus (Frank) Chester. (*Micrococcus phytophthorus* Frank, Cent. f. Bakt., II Abt., *5*, 1899, 134; Chester, Man. Determ. Bact., 1901, 67.) Associated with blight and rot of potato.

Streptococcus piima Macy. (Jour. Dairy Sci., *6*, 1923, 2.) From ropy milk, the Finnish piima.

Streptococcus pityocampae α Dufrenoy. (Compt. rend. Soc. Biol., Paris, *71*, 1919, 288.) From processionary moth larvae (*Cnethocampa pityocampa*). Motile. Gram-positive.

Streptococcus pityocampae β Dufrenoy (*loc. cit.*). From processionary moth larvae. Gram-negative.

Streptococcus pleomorphus von Wiesner. (Wien. klin. Wochnschr., 1917, 933 and 1918, 1101; see Lehmann and Neumann, Bakt. Diag., 7 Aufl., *2*, 1927, 224.) Occurred frequently during the influenza epidemic of 1918.

Streptococcus pneumosimilis Frost and Engelbrecht. (The Streptococci, 1940, 57.) From milk and from the throats of dairy employees. Not found in bovine feces.

Streptococcus polymorphus Heim. (Streptococcus, Kraskowska and Nitsch, Cent. f. Bakt., I Abt., Orig., *82*, 1918, 264; Heim, see Lehmann and Neumann, Bakt. Diag., 7 Aufl., *2*, 1927, 224.) From the throat.

Streptococcus productus Prévot. (Compt. rend. Soc. Biol., Paris, *135*, 1941, 105.) An anaerobic streptococcus from a gangrenous lung.

Streptococcus proteiformis var. *liquefaciens* Hauduroy et al. (*Enterococcus proteiformis liquefaciens* Hauduroy, Thèse Doctorat Méd., Strasbourg, 1921; Hauduroy et al., Dict. d. Bact. Path., 1937, 521.) From feces.

Streptococcus proteus Chester. (Streptococcus No. 52, Conn, Report Storrs Agr. Exp. Sta., 1894, 81; Chester, Man. Determ. Bact., 1901, 67.) From cream.

Streptococcus pseudohaemolyticus Cumming. (Jour. Path. and Bact., *30*, 1927, 279.) From sputum of patients with pulmonary tuberculosis.

Streptococcus putrefaciens Trevisan. (I generi e le specie delle Batteriacee, 1889, 31.) From putrefying blood.

Streptococcus pyogenes bovis Lucet. (Ann. Inst. Past., *7*, 1893, 325; also see Crookshank, Textbook of Bact., 4th ed., Philadelphia, 1900, 188.) From bovine pus.

Streptococcus pyogenes hominis Crookshank. (Textbook of Bact., 4th ed., Philadelphia, 1900, 187.) From human sources.

Streptococcus pyogenes nonhaemolyticus Thomson and Thomson. (Streptocoque pyogené nonhémolytique, Weissenbach, Compt. rend. Soc. Biol., Paris, *81*, 1918, 819; Thomson and Thomson, Ann. Pickett-Thomson Res. Lab., *3*, 1927, 183.) From feces and various human infections.

Streptococcus radiatus Klein. (Cent. f. Bakt., I Abt., *28*, 1900, 417.) From exudate from the udder of a cow.

Streptococcus rheumaticus Poynton and Paine. (Poynton and Paine, Lancet, *2*, September 22 and 29, 1900, 861; *Diplococcus rheumaticus* and *Micrococcus rheumaticus* Beaton and Walker, Brit. Med. Jour., January 31, 1903, 237; abst. in Cent. f. Bakt., I Abt., Ref., *33*, 1903, 528.) From cases of rheumatism and endocarditis.

Streptococcus rindfleischii Trevisan. (Streptococcus bei Mycosis fungoides, Rindfleisch, Deutsche med. Wchnschr., *11*, 1885, 233; Trevisan, I generi e le specie delle Batteriacee, 1889, 30.) From skin infection (mycosis fungoides).

Streptococcus ruber Lundstrom. (Finska Läkaresällskapets Handlingar, *35*, 1893.) Red colonies.

Streptococcus rubiginosus Jamieson and Edington. (Brit. Med. Jour., *1*, 1887, 1265.) Associated with cases of scarlet fever. Probably identical with *Micrococcus pyogenes* Klein, according to Macé (Traité Pratique de Bact., Paris, 4th ed., 1901, 425).

Streptococcus rugosus Migula. (*Streptococcus ureae* (*non pyogenes*) *rugosus* Rovsing, Die Blasenentzündungen, ihre Aetiologie, Pathogenese und Behandlung, 1890, 44; Migula, Syst. d. Bakt., *2*, 1900, 30; *Streptococcus rugosus ureae* Miquel and Cambier, Traité de Bact., Paris, 1902, 829.) From cases of cystitis.

Streptococcus salivarius brevis and *Streptococcus salivarius tenuis* Veillon. (Quoted from Thomson and Thomson, Ann. Pickett-Thomson Res. Lab., *3*, 1927, 187 and 240.) From the mouth. See *Streptococcus tenuis*.

Streptococcus sanguineus Migula. (*Diplococcus pyogenes* Pasquale, Giorn. med. d. R. esercito e d. R. marina, 1890; Migula, Syst. d. Bakt., *2*, 1900, 36.) From a case of bone tuberculosis.

Streptococcus sanguinis Chester. (*Streptococcus sanguinis canis* Pitfield, Queen's Microscopic Bulletin, Philadelphia, 1897, 44; Chester, Man. Determ. Bact., 1901, 64.) From the blood of dogs.

Streptococcus sanguis White. (*Streptococcus s.b.e.* Loewe, Plummer, Niven and Sherman, Jour. Amer. Med. Assoc., *130*, 1946, 257; White, Thesis, Cornell Univ., 1946 quoted from White and Niven, Jour. Bact., *51*, 1946, 721.) From

blood in cases of subacute bacterial endocarditis.

Streptococcus saprogenes Trevisan. (I generi e le specie delle Batteriacee, 1889, 31.) From putrefying blood.

Streptococcus saprophyticus Mandelbaum. (Ztschr. f. Hyg., *58*, 1908, 37.) See *Streptococcus anhaemolyticus vulgaris*. From mucous membranes.

Streptococcus schmidti Trevisan. (Coccus bei Fadenziehende Milch, Schmidt-Mülheim, Arch. f. d. ges. Physiol., *27*, 1882, 490; Trevisan, I generi e le specie delle Batteriacee, 1889, 31.) From ropy milk.

Streptococcus seiferti DeToni and Trevisan. (Micrococcus bei Influenza, Seifert, in Volkmann, Sammlung Klin. Vorträge, 240; DeToni and Trevisan, in Saccardo, Sylloge Fungorum, *8*, 1889, 1056.) From sputum and nasal secretions of influenza patients.

Streptococcus septicus Migula. (*Streptococcus septicus liquefians* Babes, Bakt. Unter. ü. septische Prozesse des Kindesalters, Leipzig, 1889, 22; *Streptococcus septicus liquefaciens* Babes, according to Eisenberg, Bakt. Diag., 3 Aufl., 1891, 312; Migula, Syst. d. Bakt., *2*, 1900, 27; not *Streptococcus septicus* Flügge, Die Mikroorganismen, 2 Aufl., 1886, 154.) From the blood and organs of a diseased child.

Streptococcus septopyaemicus Biondi. (Ztschr. f. Hyg., *2*, 1887, 194 and 225.) According to Migula (Syst. d. Bakt., *2*, 1900, 6) this is a synonym of *Streptococcus pyogenes*. From human saliva.

Streptococcus sornthalii (Adametz) Migula. (*Micrococcus sornthalii* Adametz, Cent. f. Bakt., II Abt., *1*, 1895, 465; Migula, Syst. d. Bakt., *2*, 1900, 20.) From milk and hard cheese.

Streptococcus sphagni Migula. (Syst. d. Bakt., *2*, 1900, 40.) From sphagnum in the Black Forest.

Streptococcus sputigenus Migula. (Syst. d. Bakt., *2*, 1900, 24.) From sputum.

Streptococcus stenos Bergey et al. (Manual, 1st ed., 1923, 50.) From a variety of human inflammatory conditions.

Streptococcus stramineus Henrici. (Arb. bakt. Inst. Karlsruhe, *1*, Heft 1, 1894, 59.) From Schlosskäse.

Streptococcus subacidus Holman. (Jour. Med. Res., *34*, 1916, 388.) From various human infections.

Streptococcus suspectus Trevisan. (Streptococco dell' ematuria, 'Pisciasangue' dei bovini; Trevisan, I generi e le specie delle Batteriacee, 1889, 30.) From blood and spleen in cases of bovine hematuria.

Streptococcus tenuis Veillon. (Arch. Méd. Exp. et Anat., *6*, 1894, 161.) From human mouth.

Streptococcus terricola van Steenberge. (van Steenberge, Ann. Inst. Past., *34*, 1920, 806; not *Streptococcus terricola* Killian and Fehér, Ann. Inst. Past., *55*, 1935, 619.) From garden soil.

Streptococcus toxicatus (Burrill) DeToni and Trevisan. (*Micrococcus toxicatus* Burrill, The Bacteria. Illinois Industrial Univ., 11th Ann. Rept., 1882, 42; DeToni and Trevisan, in Saccardo, Sylloge Fungorum, *8*, 1889, 1065.) From diseased plant tissue.

Streptococcus trifoliatus Migula. (*Diplococcus ureae (non pyogenes) trifoliatus* Rovsing, Die Blasenentzündungen, ihre Aetiologie, Pathogenese und Behanglung, 1890, 43; Migula, Syst. d. Bakt., *2*, 1900, 29.) From cases of cystitis.

Streptococcus turbidus Lehmann and Neumann. (Bouillon trübende Streptokokken, Behring, Cent. f. Bakt., *12*, 1892, 193; Lehmann and Neumann, Bakt. Diag., 1 Aufl., *2*, 1896, 125.) From various human infections, especially erysipelas. Presumably a smooth culture of *Streptococcus pyogenes*.

Streptococcus tyrogenus Henrici. (Arb. bakt. Inst. Karlsruhe, *1*, Heft 1, 1894, 50.) From cheeses.

Streptococcus ureae Migula. (*Streptococcus pyogenes ureae* Rovsing, Die Blas-

enentzündungen, ihre Aetiologie, Pathogenese und Behandlung, 1890, 45; Migula, Syst. d. Bakt., *2*, 1900, 28; not *Streptococcus ureae* Trevisan, I generi e le specie delle Batteriacee, 1889, 31.) From cases of cystitis.

Streptococcus urinae Migula. (*Diplococcus ureae* (*non pyogenes*) Rovsing, *loc. cit.*, 45; Migula, Syst. d. Bakt., *2*, 1900, 13.) From cases of cystitis.

Streptococcus vaccinae (Cohn) Zopf. (Microsphäeren der Vaccine, Cohn, Arch. f. path. Anat., *55*, 1872, 237; *Microsphaera vaccinae* Cohn quoted from Cohn, Beiträge z. Biol, d. Pflanzen, *1*, Heft, 2, 1872, 161; *Micrococcus vaccinae* Cohn, *idem;* Zopf, Die Spaltpilze, 3 Aufl., 1885, 52.) From lymph of cow pox pustules.

Streptococcus varicellae Trevisan. (Microbio della varicella, Bareggi, 1885, probably in Gazz. Med. ital. Lomb. Milano, 229-242; Trevisan, I generi e le specie delle Batteriacee, 1889, 30.) From chicken-pox pustules.

Streptococcus variolae Trevisan. (Microsphäeren der Variola, Cohn, Arch. f. path. Anat., *55*, 1872, 237; *Micrococcus variolae* Cohn, 1872, quoted from Trevisan, I generi e le specie delle Batteriacee, 1889, 30.) From lymph of small pox pustules. Regarded by Cohn (Beiträge z. Biol. d. Pflanzen, *1*, Heft 2, 1872, 161) as a variety of *Micrococcus vaccinae* Cohn.

Streptococcus variolae-ovinae (Plaut) DeToni and Trevisan. (*Micrococcus variolae ovinae* Plaut, Das organisirte Contagium der Schafpocken und die Mitigation desselben, Leipzig, 1882; DeToni and Trevisan, in Saccardo, Sylloge Fungorum, *8*, 1889, 1058.) From the lymph in sheep-pox pustules.

Streptococcus vermiformis Sternberg. (Wurmformiger *Streptococcus*, Maschek, Bakt. Unters. d. Leitmeritzer Trinkwasser, Jahresb. d. Oberrealschule zu Leitmeritz, 1887; Sternberg, Man. of Bact., 1893, 611.) From water.

Streptococcus versatilis Broadhurst. (Jour. Inf. Dis., *17*, 1915, 323.) From throat of dogs, horse and cattle feces, etc.

Streptococcus vini Migula. (*Micrococcus saprogenes vini II*, Kramer, Landwirtsch. Versuchsstat., *37*, 1890, 325 and Die Bakt. in ihren Beziehungen z. Landwirtsch. u. d. landwirtsch.-technisch. Gewerben, *2*, 1892, 140; Migula, Syst. d. Bakt., *2*, 1900, 33.) From wine.

Streptococcus viscosus Lehmann and Neumann. (Schleimiger Streptokokken, Behring, Cent. f. Bakt., *12*, 1892, 193; Lehmann and Neumann, Bakt. Diag., 1 Aufl., *2*, 1896, 125.) From various human infections. Presumably a mucoid culture of *Streptococcus pyogenes*.

Streptococcus vitulorum Trevisan. (Micrococco della diarrea bianca dei vitellini, Perroncito, 1886; Trevisan, I generi e le specie delle Batteriacee, 1889, 30.) From white diarrhoea of calves.

Streptococcus vulgaris Loening. (Münch. med. Wochnschr., *57*, 1910, 173 and 247; *Streptococcus pyogenes vulgaris* Thomson and Thomson, Ann. Pickett-Thomson Res. Lab., *3*, 1927, 189.) Names applied to *Streptococcus pyogenes*.

Streptococcus weissii Trevisan. (Atti d. Accad. Fisio-Medico-Statistica in Milano, Ser. IV, *3*, 1885, 119.) From lung exudate in pleuropneumonia of cattle.

Streptococcus zythi Trevisan. (Torulacée de la bière malade, Pasteur; Trevisan, I generi e le specie delle Batteriacee, 1889, 31.) From spoiled beer.

Streptostaphylococcus parvulus Heurlin. (Heurlin, Bakt. Unters. d. Keimgehaltes im Genitalkanale der fiebernden Wöchnerinnen. Helsingsfors, 1910, 138.) From genital canal. Intermediate between *Streptococcus anaerobius* Krönig and *Staphylococcus parvulus* Veillon and Zuber.

Genus III. **Leuconostoc** *Van Tieghem* ***emend.*** *Hucker and Pederson.**

(Van Tieghem, Ann. Sci. Nat., *6*, Sér. 7, 1878, 170; *Betacoccus* Orla-Jensen, The Lactic Acid Bacteria. Mem. Acad. Sci. Danemark, Sec. d. Sci., *5*, Sér. 8, 1919, 146; Hucker and Pederson, New York Agr. Exp. Sta. Tech. Bul. 167, 1930, 66.) From Latin *leucus*, clear, colorless; M. L. *Nostoc*, a genus of blue-green algae.

Cells normally spherical. Under certain conditions, such as in acid fruits and vegetables, the cells may lengthen and become pointed or even elongated into a rod. Certain types grow with a characteristic slime formation in sucrose media. Grow on ordinary culture media, but growth is enhanced by the addition of yeast, tomato or other vegetable extracts. Generally, a limited amount of acid is produced, consisting of lactic and acetic acid; alcohol is also formed, and about one-fourth of the fermented glucose is changed to CO_2. Levo lactic acid is always produced, and sometimes dextro lactic acid also. Milk is rarely curdled. Fructose is reduced to mannitol. Habitat: Milk, plant juices.

The type species is *Leuconostoc mesenteroides* (Cienkowski) Van Tieghem.

Key to the species of genus **Leuconostoc.**

I. Acid from sucrose.
- A. Acid from pentoses.
  - 1. *Leuconostoc mesenteroides.*
- B. No acid from pentoses.
  - 2. *Leuconostoc dextranicum.*

II. No acid from sucrose.
- 3. *Leuconostoc citrovorum.*

1. **Leuconostoc mesenteroides** (Cienkowski) Van Tieghem. (*Ascococcus mesenteroides* Cienkowski, Arb. d. Naturf. Gesellsch. a. d. Univ. a. Charkoff, 1878, 12; Van Tieghem, Ann. Sci. Nat., *6*, Sér. 7, 1878, 170; *Leuconostoc indicum* Liesenberg and Zopf, Beitr. z. Physiol. u. Morph. niederer Organis., Heft 1, 1892, 19; *Streptococcus mesenterioides* Migula, Syst. d. Bakt., *2*, 1900, 25; *Leuconostoc agglutinans* Barendrecht, Cent. f. Bakt., II Abt., *7*, 1901, 627; *Leuconostoc aller* Zettnow, Ztschr. f. Hyg., *57*, 1907, 154; *Leuconostoc opalanitza* Zettnow, *loc. cit.*; *Betacoccus arabinosaceus* Orla-Jensen, The Lactic Acid Bacteria, 1919, 152; *Leuconostoc arabinosaceus* Holland, Jour. Bact., *5*, 1920, 223; *Bacillus pleofructi* Savage and Hunwicke, Spec. Rept. Food Investigation Board, London, 1923, 134; *Leuconostoc pleofructi* Pederson, N. Y. Agr. Exp. Sta. Tech. Bull. 150 and 151, 1929.) From Greek *mesenterium*, mesentery; *eidus*, form (like).

Probable synonym: *Leuconostoc soyae* Belenky, Bull. Sci., Res. Inst. for Leguminous Crops, Moscow (Russian), *5*, 1934, 132.

Spheres: 0.9 to 1.2 microns in diameter, occurring in pairs and short or long chains. In sucrose solutions the chains are surrounded by a thick, gelatinous, colorless membrane consisting of dextran. Gram-positive.

Glucose gelatin colonies: Small, white to grayish-white, raised, nodular.

* Revised by Prof. G. J. Hucker and Prof. Carl S. Pederson, New York State Experiment Station, Geneva, New York, September, 1938; further revision, December, 1943.

Glucose gelatin stab: Growth along entire stab. No liquefaction.

Sucrose broth: Abundant growth with massive formation of slimy material.

Potato: No visible growth.

Indole not formed.

Acid from glucose, fructose, galactose, mannose, xylose, arabinose, sucrose, and generally from lactose, raffinose, salicin and mannitol. Rarely acid from dextrin, starch, inulin, sorbitol, rhamnose or glycerol.

Nitrites not produced from nitrates.

Produces slime from sucrose. Most pronounced in sucrose gelatin stab.

Aerobic, facultative.

Optimum temperature 21° to 25°C.

Distinctive characters: Active slime producer in sucrose solutions.

Source: Slime in sugar factory.

Habitat: Most active of the genus. Encountered in fermenting vegetable and other plant materials. Frequently isolated from slimy sugar solutions.

2. **Leuconostoc dextranicum** (Beijerinck) Hucker and Pederson. (*Lactococcus dextranicus* Beijerinck, Folia Microbiologica, Delft, 1912, 377; *Betacoccus bovis* Orla-Jensen, The Lactic Acid Bacteria, Copenhagen, 1919, 152 (*Leuconostoc bovis* Holland, Jour. Bact., *5*, 1920, 223); *Streptococcus paracitrovorus* Hammer, Research Bul. 63, Iowa Agr. Exp. Sta., 1920; Hucker and Pederson, N. Y. Agr. Exp. Sta. Tech. Bull. 167, 1930, 67.) From Latin *dexter*, right; M. L. *dextranum*, dextran; M. L. *dextranicus*, related to dextran.

Note: The description of Streptococcus b, v. Freudenreich (Cent. f. Bakt., II Abt., *3*, 1897, 47) renamed *Streptococcus kefir* by Migula (Syst. d. Bakt., *2*, 1900, 44) is too indefinite to permit the determination of its exact relationship to the organisms in this genus. It is clear, however, that the *Streptococcus kefir* of these authors and that of Evans (Jour. Agr. Res., *13*, 1918, 235) were very similar to if not identical with *Leuconostoc dextranicum*. *Streptococcus distendens* Hammer (Iowa State Coll. Jour. Sci., *2*, 1927, 5) may also be identical with *Leuconostoc dextranicum*.

Spheres: 0.6 to 1.0 micron in diameter, occurring in pairs and in short chains. Gram-positive.

Gelatin stab: Gray filiform growth in stab.

Agar colonies: Small, gray, circular, slightly raised, entire.

Glucose broth: Slight grayish sediment.

Litmus milk: Acid, coagulation. Frequently shows slight reduction of litmus in bottom of tube.

Potato: No visible growth.

Indole not formed.

Nitrites not produced from nitrates.

Produce slime from sucrose in rapidly growing cultures.

Acid from glucose, fructose, galactose, maltose, sucrose, and generally from lactose and mannose. No acid from xylose, arabinose, glycerol, rhamnose, sorbitol, mannitol, starch, rarely raffinose, inulin or dextrin.

Aerobic, facultative.

Optimum temperature of growth 21° to 25°C.

Distinctive characters: Produces moderate amount of slime in sucrose solutions.

Source: Dairy starters.

Habitat: Found both in plant materials and in milk products.

3. **Leuconostoc citrovorum** (Hammer) Hucker and Pederson. (*Streptococcus citrovorus* Hammer, Research Bull. No. 63, Iowa Agr. Exper. Sta., 1920; Hucker and Pederson, N. Y. Agr. Exp. Sta. Tech. Bull. 167, 1930, 67.) From Latin *citrus*, the citron tree; M. L., lemon or orange, hence citric acid; *voro*, devour.

Spheres: 0.6 to 1.0 micron in diameter, occuring in pairs and chains. Gram-positive.

Gelatin stab: Filiform growth in stab. No liquefaction.

Agar colonies: Small, gray, entire, slightly raised.

Agar slant: Small, gray, discrete colonies.

Glucose broth: Slight gray sediment.

Litmus milk: Slightly acid with partial reduction of litmus.

Potato: No visible growth.

Indole not formed.

Nitrites not produced from nitrates.

Grows poorly on ordinary media without the addition of yeast extract or other growth accessory substance.

Acid from glucose, fructose, galactose and lactose. Generally does not form acid from mannose, sucrose, maltose, xylose, arabinose, rhamnose, raffinose, glycerol, dextrin, inulin, starch, salicin, mannitol or sorbitol.

Uses citric acid in milk.

Aerobic, facultative.

Optimum temperature 20° to 25°C.

Distinctive character: Non-slime producer.

Source: Dairy products.

Habitat: Found in milk and dairy products.

Appendix: This includes species that probably belong in this genus. The descriptions are too meager to permit drawing any definite conclusion regarding their relationship to the three species recognized above.

Bacterium laevolacticum Migula. (*Bacillus acidi laevolactici* Schardinger, Monatsh. f. Chemie, *11*, 1890, 544; Migula, Syst. d. Bakt., *2*, 1900, 406; *Bacterium acidi laevolactici* Lehmann and Neumann, Bakt. Diag., 4 Aufl., *2*, 1907, 178.) From well water.

Leuconostoc lagerheimii Ludwig. (Ludwig, Lehrb. d. niederen Kryptog., 1892, 29; *Streptococcus lagerheimii* Migula, Syst. d. Bakt., *2*, 1900, 41.) From slimy sugar solutions.

Micrococcus gelatinogenus Bräutigam. (Pharmaceutische Centralhalle, 1891, No. 30.) From the air. Forms gum in sucrose media.

Micrococcus gummosus Happ. (Inaug. Diss., Basel, published in Berlin, 1893, 31.) From slimy sugar solutions.

Myxococcus betae Gonnermann. (Oesterr.- Ungar. Ztschr. f. Zuckerind. u. Landw., *136*, 1907, 883.) From sugar beet juice.

Streptococcus citrovorus-paracitrovorus Vas and Csiszár. (Milchwirtsch. Fortsch., *18*, 1936, 68.) From cream and butter.

Streptococcus hornensis Boekhout. (Cent. f. Bakt., II Abt., *6*, 1900, 162.) From slimy, sweetened condensed milk. A strong dextran former. Related to *Leuconostoc mesenteroides*.

Zoogloea termo Cohn. (Cohn, Nov. Act. Acad. Caes. Leop.-Carol. Nat. Cur., *24*, 1854, 123.) The only species in the genus *Zoogloea* as originally proposed. From running water. Scheibler used this name for a zoogloea-forming organism from slimy sugar solutions in Neue Ztschr. f. Rübenzucker- Ind., *1*, 1878, 366 and probably also in Ztschr. d. Vereins f. Rübenzucker- Ind., 1874, 330. The latter reference apparently is not available in America. See Buchanan, General Syst. Bact., 1925, 530 for a history of the genus *Zoogloea*.

TRIBE II. LACTOBACILLEAE WINSLOW ET AL.

(Jour. Bact., *5*, 1920, 211.)

Rods, often long and slender. Non-motile. Gram-positive. Pigment formation rare. When present, yellow or orange, to rust or brick-red in color. Poor surface growth (except in genus *Microbacterium*) because these bacteria are generally microaerophilic or anaerobic. Carbohydrates and polyalcohols are changed either by homofermentation to lactic acid or by heterofermentation to lactic, acetic, propionic or butyric acids, alcohol and carbon dioxide. Growth on potato is poor or absent. Gelatin is not liquefied. Nitrates are not reduced (except in genus *Microbacterium*). Several species grow at relatively high temperatures. May or may not produce catalase.

Key to the genera of tribe **Lactobacilleae.**

I. Always produce lactic acid from carbohydrates.
  a. Catalase negative. Microaerophilic.
    Genus I. *Lactobacillus*, p. 349.
  aa. Catalase positive. Aerobic.
    Genus II. *Microbacterium*, p. 370.
II. Ferments carbohydrates, polyalcohols and lactic acid with the formation of propionic and acetic acids, and carbon dioxide. Catalase positive.
    Genus III. *Propionibacterium*, p. 372.
III. Ferments carbohydrates, polyalcohols and lactic acid with the formation of butyric and acetic acids, and carbon dioxide. Generally catalase negative.
    Genus IV. *Butyribacterium*, p. 379.

Genus I. **Lactobacillus** *Beijerinck.**

(? *Dispora* Kern, Biol. Zent., *2*, 1882, 135; ?*Tyrothrix* Duclaux, Ann. Inst. Nat. Agron., *4*, 1882, 79; ?*Pacinia* Trevisan, Atti della Accad. Fisio-Medico-Statistica in Milano, Ser. 4, *3*, 1885, 83; ?*Saccharobacillus* van Laer, Contributions à l'histoire des ferments des hydrates de carbone. Mém. Acad. Royale de Belgique, *43*, 1889; *Lactobacter* Beijerinck, Cent. f. Bakt., II Abt., *6*, 1900, 200; Beijerinck, Arch. néerl. d. sci. exact. et nat. Haarlem, Sér. 2, *7*, 1901, 212; *Streptobacillus* Rist and Khoury, Ann. Inst. Past., *16*, 1902, 70; ?*Brachybacterium* Troili-Petersson, Cent. f. Bakt., II Abt., *11*, 1903, 138; *Caseobacterium* Orla-Jensen, Cent. f. Bakt., II Abt., *22*, 1909, 336; *Plocamobacterium* Löwi, Wiener klin. Wochnschr., *33*, 1920, 730 (in part); *Lactobacterium* van Steenberge, Ann. Inst. Past., *34*, 1920, 806; *Bifidobacterium* Orla-Jensen, Le Lait, *4*, 1924, 469; *Acidobacterium* Heim, see Schlirf, Cent. f. Bakt., I Abt., Orig., *97*, 1925, 111: *Bifidibacterium* Prévot, Ann. Inst. Past., *60*, 1938, 303.) From M. L., lactic and *bacillus*, a rod.

Rods, usually long and slender. Microaerophilic. Carbohydrates and poly-alcohols are changed by homofermentation to lactic acid, or by heterofermentation to lactic and acetic acids, alcohols and carbon dioxide. Catalase negative. Found in fermenting animal (especially dairy) and plant products.

The type species is *Lactobacillus caucasicus* Beijerinck.

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* Completely revised by Prof. Carl S. Pederson, New York State Experiment Station, Geneva, New York, in consultation with Prof. J. M. Sherman, Cornell University, Ithaca, New York and Prof. L. F. Rettger, Yale University, New Haven, Conn., June, 1938; further revision by Prof. Carl S. Pederson, January, 1945.

Key to the species of genus **Lactobacillus.**

I. Produce only traces of by-products other than lactic acid. Homofermentative.
  A. Optimum temperature 37° to 60°C or higher. Sub-genus *Thermobacterium* Orla-Jensen (The Lactic Acid Bacteria, 1919, 160).
    1. Acid from lactose.
      a. Optimum temperature 37° to 45°C.
        b. Produce levo lactic acid.
          1. *Lactobacillus caucasicus.*
          2. *Lactobacillus lactis.*
        bb. Produce inactive or dextro lactic acid.
          c. Microaerophilic.
            3. *Lactobacillus helveticus.*
            4. *Lactobacillus acidophilus.*
          cc. Anaerobic in freshly isolated cultures.
            5. *Lactobacillus bifidus.*
      aa. Optimum temperature 45° to 62°C; usually no acid from maltose.
        6. *Lactobacillus bulgaricus.*
        7. *Lactobacillus thermophilus.*
    2. No acid from lactose.
        8. *Lactobacillus delbrueckii.*
  B. Optimum temperature 28° to 32°C. Sub-genus *Streptobacterium* Orla-Jensen (*loc. cit.*, 166).
    1. Acid from lactose.
      a. Produces dextro lactic acid. Often prefers lactose to sucrose and maltose.
        9. *Lactobacillus casei.*
      aa. Produces inactive lactic acid.
        10. *Lactobacillus plantarum.*
    2. No acid from lactose.
        11. *Lactobacillus leichmannii.*

II. Produce considerable amounts of by-products other than lactic acid (carbon dioxide, alcohol and acetic acid; mannitol from fructose). Heterofermentative. Sub-genus *Betabacterium* Orla-Jensen (*loc. cit.*, 175).*
  A. Optimum temperature 28° to 32°C. Usually ferment arabinose.
    1. Does not ferment raffinose, and usually does not ferment sucrose or lactose.
        12. *Lactobacillus brevis.*
    2. Ferment raffinose, sucrose and lactose.
        13. *Lactobacillus buchneri.*
        14. *Lactobacillus pastorianus.*
  B. Optimum temperature 35° to 40°C or higher. Usually does not ferment arabinose.
        15. *Lactobacillus fermenti.*

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* Also see discussion of *Betabacterium caucasicum*, p. 358.

1. **Lactobacilus caucasicus** Beijerinck. (*Bacillus caucasicus* Beijerinck, Arch. néerl. d. sci. exact. et nat., *23*, 1889, 428; Beijerinck, *ibid.*, Sér. 2, *7*, 1901, 212; not *Bacillus caucasicus* v. Freudenreich, Cent. f. Bakt., II Abt., *3*, 1897, 54 and 135; *Bacterium caucasicus* Chester, Ann. Rept. Del. Col. Agr. Exp. Sta., *9*, 1897, 130; not *Bacterium caucasicum* Lehmann and Neumann, Bakt. Diag., 2 Aufl., *2*, 1899, 209; not *Betabacterium caucasicum* Orla-Jensen, The Lactic Acid Bacteria, 1919, 175.) From Greek *Caucasia*, M. L. *caucasicus*, of the Caucasus.

The following is a possible or probable synonym: *Streptobacillus lebenis* Rist and Khoury, Ann. Inst. Past., *16*, 1902, 70.

Description taken from the two reports of Beijerinck (*loc. cit.*).

Rods: Thin and variable in size, occurring singly or in filaments. Non-motile. Non-spore-forming. Gram-positive (not recorded in early descriptions).

Gelatin: No liquefaction.

Wort gelatin: Small, white colonies.

Agar colonies: Small.

Broth: Carbohydrates necessary for growth.

Milk: Rapid acid production with coagulation, no action in casein.

Utilizes animal peptones with difficulty, utilizes vegetable peptones more readily.

Acid from glucose, sucrose, maltose and lactose. No action on starch. Action on other carbohydrates not studied. Lactose in milk converted to levo lactic acid with little carbon dioxide.

Microaerophilic.

Optimum temperature 40° to 44°C. Temperature range 25° to 45°C.

Source: From kefir and cheese.

Habitat: Occurs symbiotically with yeast in kefir.

Prototype: *Dispora caucasica* Kern. (Kern, Biol. Zent., *2*, 1882, 135; later in Bull. de la Soc. Imp. des Naturalistes de Moscow, *56*, 1882, 168; *Bacterium caucasicum* Zopf, Die Spaltpilze, 3 Aufl., 1885, 90; *Bacillus kaukasicus* Flügge, Die Mikroorganismen, 2 Aufl., 1886, 270; *Pacinia caucasica* Trevisan, I generi e le specie delle Batteriacee, 1889, 23.)

The description by Kern of an organism from kefir grains is confused probably because the organism (a spore former) which he isolated by the use of Cohn's solution was not the same as the presumably granulated lactobacillus he saw in microscopical preparations of kefir. Beijerinck was apparently the first to have isolated a lactobacillus from kefir in pure culture and to have given a sufficiently complete description to make reidentification possible. It should be noted that from the characters given, this could not have been the same species as that isolated later from kefir by v. Freudenreich (*loc. cit.*) and Orla-Jensen (*loc. cit.*).

2. **Lactobacillus lactis** (Orla-Jensen) Holland. (*Bacillus lactis acidi* Leichmann, Cent. f. Bakt., II Abt., *2*, 1896, 779; Milch. Zeitung, *25*, 1896, 67; *Thermobacterium lactis* Orla-Jensen, The Lactic Acid Bacteria, 1919, 164; *Lactobacillus lactis-acidi* Holland, Jour. Bact., *5*, 1920, 223; Holland, *idem.*) From Latin *lac*, milk.

Henneberg (Handb. der Gärungsbakt., 2 Aufl., *2*, 1926, 128) regards *Bacillus lactis acidi* Leichmann as identical with *Thermobacterium lactis* Orla-Jensen.

Rods: Long forms with a tendency to grow into threads, often strongly curling. Occur singly or in pairs in young vigorous cultures. Generally contain volutin grains. Gram-positive (not recorded in original description).

Milk: Acid produced followed by coagulation in one to four days. 1.7 per cent acid produced.

Acid from fructose, glucose, mannose, galactose, sucrose, maltose, lactose, raffinose and dextrin. Glycerol, xylose, arabinose, rhamnose, sorbitol, mannitol, inulin and starch not fermented. Salicin may or may not be fermented.

Forms levo lactic acid with only a trace of other products.

Temperature relations: Optimum 40°C.

Minimum 18° to 22°C. Maximum 50°C.

Source: From milk and cheese.

Habitat: Undoubtedly widely distributed in milk or milk products.

3. **Lactobacillus helveticus** (Orla-Jensen) Holland. (*Bacillus* ε, von Freudenreich, Cent. f. Bakt., II Abt., *1*, 1895, 173; also Landw. Jahrb. d. Schweiz, 1895, 211; *Bacillus casei* ε, v. Freudenreich and Thöni, Landw. Jahrb. d. Schweiz, 1904, 526; also Orla-Jensen, Cent. f. Bakt., II Abt., *13*, 1904, 609; *Caseobacterium* ε, Orla-Jensen, Cent. f. Bakt., II Abt., *22*, 1909, 337; *Thermobacterium helveticum* Orla-Jensen, Maelkeri-Bakteriologie, 1916, 35; also the Lactic Acid Bacteria, 1919, 164; *Bacterium casei* ε, Holland, Jour. Bact., *5*, 1920, 221; Holland, *ibid.*, 223.) From Latin *helveticus*, Swiss.

Rods: 0.7 to 0.9 by 2.0 to 6.0 microns, occurring singly and in chains. Non-motile. Gram-positive.

Whey gelatin colonies: Does not grow readily at temperatures required for incubation of gelatin.

Lactose agar colonies: Small, grayish, viscid.

Milk: Acid, with coagulation; may become slimy.

Nitrites not produced from nitrates.

Acid from glucose, fructose, galactose, mannose, maltose, lactose, and smaller amounts from dextrin. The lactic acid is inactive.

Temperature relations: Optimum 40° to 42°C. Minimum 20° to 22°C. Maximum 50°C.

Microaerophilic.

Source: From sour milk and cheese.

Habitat: Widely distributed in dairy products.

4. **Lactobacillus acidophilus** (Moro) Holland. (*Bacillus acidophilus* Moro, Wiener klin. Wochnschr., *13*, 1900, 114; also Jahrb. f. Kinderheilkunde, *52*, 1900, 38; Holland, Jour. Bact., *5*, 1920, 215; *Plocamobacterium acidophilum* Lehmann and Neumann, Bakt. Diag., 7 Aufl., *2*, 1927, 510; *Thermobacterium intestinale* Orla-Jensen, Orla-Jensen and Winther, Cent. f. Bakt., II Abt., *93*, 1936, 321.) From Latin *acidus*, sour; M. L. *acidus*, acid and Greek *philus*, loving.

Possible synonyms: Milchsäurebacillus, Boas and Oppler, Deutsche med. Wochnschr., *21*, 1895, 73; Diagnostik und Therapie d. Magenkrankheiten, II Teil, 1907, 265 (*Lactobacillus boas-oppleri* Bergey et al., Manual, 1st ed., 1923, 243); *Bacillus exilis* Tissier, La flore intestinale des nourrissons, Paris, 1900, 102; *Bacillus gastrophilus* Lehmann and Neumann, Bakt. Diag., 4 Aufl., *2*, 1907, 424 (*Bacterium gastrophilum* Lehmann and Neumann, Bakt. Diag., 5 Aufl., *2*, 1912, 305); *Bacillus acetogenus* α Distaso, Cent. f. Bakt., I Abt., Orig., *59*, 1911, 49; *Bacillus acetogenus* β Distaso, *ibid.*, 51; *Bacillus acetogenus proteiformis* Distaso, *ibid.*, 52; *Bacillus acetogenus exilis* Distaso, *ibid.*, 53; *Bacillus paraexilis* Distaso, *ibid.*, *56*; *Bacillus dimorphus* Distaso, *ibid.*, 55; *Bacillus dimorphus* var. *longa* Distaso, Cent. f. Bakt., I Abt., Orig., *62*, 1912, 440; (*Bacteroides dimorphus* Bergey et al., Manual, 1st ed., 1923, 258); *Streptobacillus longus* Distaso, *ibid.*, 439; *Thermobacterium acidophilum* Henneberg, Cent. f. Bakt., II Abt., *91*, 1934, 102.

Description of Moro supplemented by material from Kulp and Rettger, Jour. Bact., *9*, 1924, 357; Curran, Rogers and Whittier, Jour. Bact., *25*, 1933, 595; and Rettger, Levy, Weinstein and Weiss, *Lactobacillus acidophilus*, Yale Univ. Press, New Haven, 1935.

Rods: 0.6 to 0.9 by 1.5 to 6.0 microns, occurring singly, in pairs and in short chains with rounded ends. Non-motile. Dimensions variable (Kulp and Rettger), (Curran, Rogers and Whittier). Gram-positive; old cultures often Gram-negative (Moro).

Gelatin: No growth at 20°C. No liquefaction.

Wort-agar (Moro) or tomato agar (Kulp and Rettger) plates: Surface colonies, peripheries a capilliform maze of long, delicate, twisted, fuzzy projections, center appears as a thick, dark, felt-like

mass. Deep colonies, small, irregularly shaped, with fine radiate or ramified projections.

Wort-agar slants: Growth scanty, limited, dry, veil-like.

Wort-broth: After 48 hours, fine, flocculent sediment. Other acid broths sediment whitish, slight turbidity.

Milk: Slow growth with small inoculum. Coagulates from the bottom up.

Potato: No growth.

Acid but no gas from glucose, sucrose and lactose (Moro). Acid from glucose, fructose, galactose, mannose, maltose, lactose and sucrose. Some cultures ferment raffinose and trehalose and have slight action on dextrin. Xylose, arabinose, rhamnose, glycerol, mannitol sorbitol, dulcitol and inositol not fermented (Kulp and Rettger). Inactive lactic acid and volatile acids formed from sugars (Curran, Rogers and Whittier).

No visible growth in carbohydrate-free media (Rettger, Levy, Weinstein and Weiss).

Optimum temperature 37°C. No growth at 20° to 22°C (Moro). Maximum temperature 43° to 48°C (Curran, Rogers and Whittier).

Not pathogenic for laboratory animals.

Microaerophilic.

Distinctive characters: Grows in acid media. Unless frequent transfers are made, organism may become Gram-negative and rapidly develop characteristic degeneration forms (Moro). The so-called original strains of *Bacillus acidophilus* from the Král collection, described and called *Microbacterium lacticum* by Orla-Jensen, do not have the characteristics given by Moro.

Source: From the feces of milk-fed infants. Also from the feces of older persons on high milk or lactose or dextrin-containing diets.

Habitat: As for source.

5. Lactobacillus bifidus (Tissier) Holland. (*Bacillus bifidus communis* and *Bacillus bifidus* Tissier, Recherches sur la flore intestinal des nourrissons, Paris, 1900, 85; *Bacteroides bifidus* Castellani and Chalmers, Man. Trop. Med., 3rd ed., 1919, 960; Holland, Jour. Bact., *5*, 1920, 223; *Nocardia bifida* Vuillemin, Encyclopédie Mycolog., Paris, *2*, Champignons Parasites, 1931, 132; *Actinomyces bifidus* Nannizzi, in Pollacci, Trat. Micopat. Umana, *4*, 1934, 13; *Cohnistreptothrix bifidus* Negroni and Fisher, Rev. Soc. Argentina Biol., *20*, 1944, 315.) From Latin *bifidus* split in two, cleft.

Possible synonyms: *Coccobacillus oviformis* Tissier, Ann. Inst. Past., *22*, 1908, 189 (*Bacterium oviforme* Le Blaye and Guggenheim, Manual pratique de diagnostique Bactériologie, Paris, 1914; *Bacteroides oviformis* Levine and Soppeland, Iowa Engineering Exp. Sta. Bul. 77, 1926, 35); *Bacillus ventriosus* Tissier, *loc. cit.* (*Bacteroides ventriosus* Eggerth, Jour. Bact., *30*, 1935, 281); *Diplobacillus acuminatus* Distaso, *loc. cit.* (*Bacteroides acuminatus* Bergey et al., Manual, 1st ed., 1923, 260).

Description supplemented from Weiss and Rettger, Jour. Bact., *28*, 1934, 501.

Small, slender rods: Average length 4.0 microns, 0.5 to 0.7 by 2 to 8 microns (Weiss and Rettger), occurring singly or in pairs and short chains, parallel to each other, very variable in appearance. Branched and club forms develop in some cultures. Non-motile. Gram-positive but stains irregularly in old cultures (Tissier).

Little or no growth in carbohydrate-free agar (Weiss and Rettger).

Deep sugar-agar colonies: After 3 days, solid with slightly irregular edge, whitish. Grow up to 3 cm from the surface forming a ring. Average diameter 3 mm. No gas.

Sugar broth: Good growth. Turbid within 3 days. Clears with flocculent precipitate.

Milk: Good growth with large inoculum. No coagulation (Tissier). May or may not coagulate milk (Weiss and Rettger).

Acid but no gas from glucose (Tissier). Acid from glucose, fructose, galactose,

sucrose, inulin and usually from dextrin, starch, maltose, raffinose and trehalose. A few strains form acid from lactose and salicin. The acid consists of inactive lactic acid and 18 to 25 per cent of volatile acid (Weiss and Rettger).

Optimum temperature 37°C. May show slight growth at 20°C. Killed at 60°C in 15 minutes.

Non-pathogenic for mice or guinea pigs.

Strict anaerobe (Tissier). Strict anaerobe in primary culture becoming microaerophilic (Weiss and Rettger).

Distinctive characters: Bifurcations and club-shaped forms (Tissier), particularly in infant feces and in primary culture (Weiss and Rettger).

Source: From feces of nursing infants.

Habitat: Very common in the feces of infants. May constitute almost the entire intestinal flora of breast-fed infants. Also present in smaller numbers with bottle-fed infants. Possibly more widely distributed than indicated in the intestines of warm-blooded animals.

5a. *Lactobacillus parabifidus* Weiss and Rettger. (*Bacterium bifidum* Orla-Jensen, The Lactic Acid Bacteria, 1919, 192; *Bacteroides bifidus* (Group 2) Eggerth, Jour. Bact., *30*, 1935, 295; *Lactobacillus bifidus II* or *Lactobacillus parabifidus* Weiss and Rettger, Jour. Bact., *35*, 1938, 17; Jour. Inf. Dis., *62*, 1938, 115.)

This is the more anaerobic variety of the bifid organisms from feces and seems to be more common in the intestine of adults. In contrast to *Lactobacillus bifidus*, it produces more volatile acid as well as dextro lactic acid, and ferments arabinose, xylose and melezitose but not mannose.

6. **Lactobacillus bulgaricus** (Luerssen and Kühn) Holland. (*Bacillus A*, Grigoroff, Revue Méd. Suisse romande, *25*, 1905; *Bacillus bulgaricus* Luerssen and Kühn, Cent. f. Bakt., II Abt., *20*, 1907, 241; *Thermobacterium bulgaricum* Orla-Jensen, The Lactic Acid Bacteria, 1919, 164; Holland, Jour. Bact., *5*, 1920, 215; *Acidobacterium bulgaricum* Schlirf, Cent. f. Bakt., I Abt., Orig., *97*, 1925, 116; *Plocamobacterium bulgaricum* Lehmann and Neumann, Bakt. Diag., 7 Aufl., *2*, 1927, 511.) From Latin *bulgaricus*, of or related to Bulgaria.

Probable synonyms: *Lactobacillus longus* Beijerinck, Arch. néerl. d. sci. exact. et nat., Sér. 2, *7*, 1901, 212 (not *Lactobacillus longus* Bergey et al., Manual, 4th ed., 1934, 312); *Bacterium casei filans* Gorini, Rend. R. Acc. Lincei, *21*, 1912, 472; Cent. f. Bakt., II Abt., *37*, 1913, 1.

Description of Luerssen and Kühn supplemented by Grigoroff, *loc. cit.;* Cohendy, Compt. rend. Soc. Biol. Paris, *58*, 1906, 364; Kuntze, Cent. f. Bakt., II Abt., *21*, 1908, 737; Bertrand and Duchacek, Ann. Inst. Past., *23*, 1909, 402; White and Avery, Cent. f. Bakt., II Abt., *25*, 1910, 161; Rahe, Jour. Bact., *3*, 1918, 420; Orla-Jensen, The Lactic Acid Bacteria, 1919, 164; Kulp and Rettger, Jour. Bact., *9*, 1924, 357; Sherman and Hodge, Jour. Dairy Sci., *19*, 1936, 494.

Rods: Slender rods with rounded ends, often in chains. Non-motile. Gram-positive, older cultures showing unstained portions (Luerssen and Kühn).

Whey gelatin: No liquefaction (White and Avery).

Colonies: Flat, yellowish-white, 2 to 3 mm. Old cultures have dark centers. Deep colonies globular (Luerssen and Kühn).

Whey agar colonies: Circular to irregular (White and Avery).

Milk: Coagulation at 37°C. No gas. No decomposition of casein.

Potato: Yellow-white colonies (Luerssen and Kühn). No growth (Grigoroff), (Cohendy), (White and Avery).

Indole not formed (Grigoroff), (White and Avery).

Nitrites not produced from nitrates.

Results on acid production from sugars vary. Glucose, lactose and galactose are apparently always fermented while xylose, arabinose, sorbose, rhamnose, dulcitol, mannitol, dextrin, inulin and starch

are never fermented. Early workers (Gigoroff) (Cohendy) noted fermentation of fructose, maltose and sucrose. Later workers (Bertrand and Duchacek), (Orla-Jensen), (Rahe), (Kulp and Rettger), (Sherman and Hodge) noted variable or negative results on sucrose, maltose and unheated fructose.

Forms high acidity in milk. The lactic acid is inactive (Grigoroff), (Bertrand and Duchacek), (White and Avery) or levo (White and Avery), (Orla-Jensen) with small quantities of volatile acid (White and Avery).

Aerobic or anaerobic (Luerssen and Kühn). Microaerophilic (White and Avery). Anaerobic in fresh isolation (Sherman and Hodge).

Optimum temperature 45° to 50°C. Minimum 22°C (Luerssen and Kühn).

Distinctive characters: This species at present is regarded as including the high temperature organisms isolated from milk with difficulty. These ferment glucose, galactose and lactose but usually do not ferment sucrose, maltose or unheated fructose when freshly isolated.

Source: Originally isolated from yoghurt.

Habitat: Probably present in many milk products if held at high temperature.

7. **Lactobacillus thermophilus** Ayers and Johnson. (Jour. Bact., *9*, 1924, 291.) From Greek *thermos*, heat and *philus*, loving.

Description of Ayers and Johnson supplemented by material from Charlton, Jour. Dairy Sci., *15*, 1932, 393.

Rods: 0.5 by 3.0 microns. Stains irregularly. Non-motile (Charlton). Gram-positive.

Gelatin stab: No liquefaction.

Agar plate: Small colonies.

Agar slant: Slight, translucent growth (Charlton).

Broth: Turbid (Charlton).

Litmus milk: Acid.

Nitrites not produced from nitrates (Charlton).

Acid from glucose, lactose, sucrose, starch and trace from glycerol. No acid from salicin, mannitol, raffinose or inulin. (Ayers and Johnson). Acid from fructose, galactose, mannose, maltose, raffinose and dextrin. No acid from arabinose, xylose, glycerol, rhamnose, salicin, inulin or mannitol. Dextro lactic acid formed. (Charlton).

This is the thermophilic lactobacillus obtained from pasteurized milk which causes pin-point colonies on agar plates.

Temperature relations: Optimum temperature 50° to 62.8°C. Minimum 30°C. Maximum 65°C. Thermal death point 71°C for 30 minutes or 82°C for 2½ minutes.

Facultative anaerobe. Grows best aerobically.

Source: From pasteurized milk.

Habitat: Known only from pasteurized milk.

8. **Lactobacillus delbrueckii** (Leichmann) Beijerinck. (*Bacillus delbrückii* Leichmann, Cent. f. Bakt., II Abt., *2*, 1896, 284; *Bacillus acidificans longissimus* Lafar, Cent. f. Bakt., II Abt., *2*, 1896, 195; *Bacillus* (?) *acidificans* Migula, Syst. d. Bakt., *2*, 1900, 801; Beijerinck, Arch. néerl. d. sci. exactes et nat., Haárlem, Sér. 2, 7, 1901, 212; *Thermobacterium cereale* Orla-Jensen, The Lactic Acid Bacteria, 1919, 164; *Bacillus acidificans-longissimus* Holland, Jour. Bact., *5*, 1920, 216; *Lactobacillus acidificans-longissimus* Holland, *ibid.*, 216; *Lactobacillus cereale* Holland, *ibid.*, 223; *Lactobacterium delbrucki* (sic) van Steenberge, Ann. Inst. Past., *34*, 1920, 820.) Named for Prof. M. Delbrück, German bacteriologist.

Description of Leichmann supplemented by material from Henneberg, Cent. f. Bakt., II Abt., *11*, 1903, 154.

Rods: 0.5 to 0.8 by 2.0 to 9.0 microns (Henneberg), occurring singly and in short chains. Non-motile. Gram-positive.

Gelatin colonies: Small, gray, circular, not liquefied.

Agar colonies: Small, flat, crenated.

Agar slant: Narrow, translucent, soft, grayish streak.

Broth: Slightly turbid.

Milk: Unchanged.

Nitrites not produced from nitrates.

Acid from maltose and sucrose (Leichmann) and glucose, fructose, galactose and dextrin. No acid from xylose, arabinose, rhamnose, lactose, raffinose, trehalose, inulin, starch, mannitol or α-methyl-glucoside (Henneberg). Levo rotatory lactic acid is formed. Forms 1.6 per cent acid in mash.

This is the high temperature organism of fermenting mashes. In fresh isolations it apparently has a higher optimum temperature than when held in pure culture.

Optimum temperature 45°C.

Microaerophilic.

Source: From sour potato mash in a distillery.

Habitat: Fermenting vegetable and grain mashes.

9. **Lactobacillus casei** (Orla-Jensen) Holland. (*Bacillus α*, v. Freudenreich, Ann. d. Microg., *2*, 1890, 266; also Landw. Jahrb. d. Schweiz, 1891, 20; *Bacillus casei α*, von Freudenreich and Thöni, Landw. Jahrb. d. Schweiz, 1904, 526; also Orla-Jensen, Cent. f. Bakt., II Abt., *13*, 1904, 609; *Caseobacterium vulgare* Orla-Jensen, Maelkeri-Bakteriologie, 1916, 35; *Streptobacterium casei* Orla-Jensen, The Lactic Acid Bacteria, 1919, 166; *Bacterium casei α*, Holland, Jour. Bact., *5*, 1920, 221; Holland, *ibid.*) From Latin *caseus*, cheese.

Rods: Short or long chains of short or long rods. Non-motile. Gram-positive.

Milk: Acid with coagulation in 3 to 5 days or longer, may become slimy. Forms about 1.5 per cent lactic acid.

Utilizes casein and therefore important in cheese ripening.

Acid from glucose, fructose, mannose, galactose, maltose, lactose, mannitol and salicin. May or may not ferment sucrose. Mostly dextro lactic acid formed though a small amount of levo lactic acid may be formed. Only lactic acid produced with a trace of other by-products.

This is the more common lactic acid rod found in milk and milk products. Orla-Jensen distinguishes it from *Lactobacillus plantarum* in that it produces dextro lactic acid and usually ferments lactose more readily than sucrose or maltose.

Temperature relations: Optimum 30°C. Minimum 10°C. Maximum 37° to 40°C and with some strains 45°C.

Microaerophilic.

Source: From milk and cheese.

Habitat: Probably more widely distributed than indicated by isolations.

10. **Lactobacillus plantarum** (Orla-Jensen) Holland. (*Streptobacterium plantarum* Orla-Jensen, The Lactic Acid Bacteria, Copenhagen, 1919, 174; Holland, Jour. Bact., *5*, 1920, 225.) From Latin *planta*, sprout; M. L., a plant.

Probable synonyms: *Bacillus pabuli acidi II* Weiss, Inaug. Diss., Göttingen, 1898; Cent. f. Bakt., II Abt., *5*, 1899, 599 (*Lactobacillus pabuliacidi* Bergey et al., Manual, 1st ed., 1923, 247); *Bacillus cucumeris fermentati* Henneberg, Ztschr. f. Spiritusindustire, *26*, 1903, 22; Cent. f. Bakt., II Abt., *11*, 1903, 166 (*Lactobacillus cucumeris* Bergey et al., Manual, 1st ed., 1923, 250); *Bacillus wortmannii* Henneberg, Cent. f. Bakt., II Abt., *11*, 1903, 162 (*Lactobacillus wortmannii* Bergey et al., Manual, 3rd ed., 1930, 288); *Bacillus listeri* Henneberg, Ztschr. f. Spiritusindustrie, *26*, 1903, 22; Cent. f. Bakt., II Abt., *11*, 1903, 161 (*Lactobacterium listeri* van Steenberge, Ann. Inst. Past., *34*, 1920, 814; *Lactobacillus listeri* Bergey et al., Manual, 1st ed., 1923, 248); *Bacillus maercki* Henneberg, *loc. cit.*; *Bacillus leichmanni II* Henneberg, *loc. cit.*; *Bacillus beijerinckii* Henneberg, Ztschr. f. Spiritusindustrie, *26*, 1903, 22; see

Cent. f. Bakt., II Abt., *11*, 1903, 159 (*Lactobacillus beijerinckii* Bergey et al., Manual, 1st ed., 1923, 248); *Lactobacillus pentosus* Fred, Peterson and Anderson, Jour. Biol. Chem., *48*, 1921, 410; Jour. Biol. Chem., *53*, 1922, 111; *Lactobacillus arabinosus* Fred, Peterson and Anderson, Jour. Biol. Chem., *48*, 1921, 410; *Bacterium busae asiaticae* Tschekan, Cent. f. Bakt., II Abt., *78*, 1929, 89 (*Lactobacillus busaeasiaticus* Bergey et al., Manual, 3rd ed., 1930, 288); *Bacterium brassicae* Wehmer, Cent. f. Bakt., II Abt., *10*, 1903, 628 (*Lactobacillus brassicae* LeFevre, Abst. Bact., *6*, 1922, 25).

Description from Orla-Jensen supplemented by material from Pederson, Jour. Bact., *31*, 1936, 217.

Rods: Ordinarily 0.7 to 1.0 by 3.0 to 8.0 microns, occurring singly or in short chains, with rounded ends. Under favorable growth conditions these organisms tend to be short rods. Under adverse conditions they tend to be longer; for example, in tomato juice agar at 45°C (Pederson, N. Y. Agr. Exp. Sta. Tech. Bull. 150, 1929). In fermenting vegetables, the organisms tend to become longer as the acidity becomes greater. The organisms are usually longer in milk than in broths. Differences in morphology are well illustrated by Orla-Jensen. Non-motile. Gram-positive.

Gelatin-yeast extract-glucose stab: Filiform growth. No liquefaction.

Agar slant: Growth, if any, is very faint.

Broth: Turbid, clearing after a few days. A few strains flocculate.

Litmus milk: Acid, usually coagulated.

Nitrites not produced from nitrates.

The majority of strains form acid from glucose, fructose, mannose, galactose, arabinose, sucrose, maltose, lactose, raffinose and salicin, and to a lesser extent, from sorbitol, mannitol, dextrin, glycerol and xylose. Rhamnose, starch and inulin usually not fermented.

Lactic acid (usually inactive) with only small quantities of acetic acid and carbon dioxide is formed in the fermentation of hexose sugars. Acetic and lactic acid are produced from the pentoses. Forms up to 1.2 per cent acid in broth.

This species is the inactive lactic acid-producing rod from fermenting materials but is closely related to *Lactobacillus casei*. It ferments sucrose and maltose as readily as lactose.

Salt tolerance: Usually grows in salt up to 5.5 per cent.

Temperature relations: Optimum temperature 30°C. Minimum 10°C. Maximum 40°C. Thermal death point 65° to 75°C for 15 minutes.

Microaerophilic.

Sources from which isolated: Milk, cheese, butter, kefir, feces, fermenting potatoes, beets, corn, chard, bread dough, sauerkraut, cucumber pickles, tomato pickles, cauliflower pickles and spoiled tomato products.

Habitat: Widely distributed in nature, particularly in fermenting plant and animal products.

10a. *Lactobacillus plantarum* var. *rudensis* Breed and Pederson (not Peterson). (Jour. Bact., *36*, 1938, 667.) This chromogenic organism isolated from cheese is one of two species responsible for the development of rusty spots in cheese. It is impossible to determine whether the incompletely described species *Bacillus rudensis* Connell, Canadian Dept. of Agric., Dairying Service, Ottawa, Report for 1897, 7 is identical with this variety of *Lactobacillus plantarum* or with *Lactobacillus brevis* var. *rudensis* (see species No. 12a). This chromogenesis is produced in starch media under anaerobic conditions.

11. **Lactobacillus leichmannii** Bergey et al. (*Bacillus leichmanni I*, Henneberg, Ztschr. f. Spiritusindustrie, *26*, 1903, 22; see Cent. f. Bakt., II Abt., *11*, 1903, 163; Bergey et al., Manual, 2nd ed., 1925, 180.) Named for Prof. G. Leichmann, a German bacteriologist.

Probable synonym: *Bacillus leichmanni III*, Henneberg, *loc. cit.*

Rods: 0.6 by 2.0 to 4.0 microns, occurring singly and in short chains. The cells show two or more deeply-staining granules. Non-motile. Gram-positive.

Gelatin stab: No liquefaction.

Agar colonies: Small, clear with white centers.

Agar slant: Limited, grayish streak, better growth in stab.

Broth: Turbid.

Nitrites not produced from nitrates.

Acid from glucose, fructose, maltose, sucrose, trehalose, and slight amounts from galactose, mannitol and α-methyl-glucoside. Lactose, raffinose, arabinose, rhamnose, dextrin and inulin not fermented. Forms 1.3 per cent lactic acid in mash.

Optimum temperature 36°C. Maximum 40° to 46°C.

Microaerophilic.

The species is apparently similar to *Lactobacillus delbrueckii* but has a lower optimum temperature.

Source: From compressed yeast and from fermenting milk.

Habitat: Dairy and plant products.

12. **Lactobacillus brevis** (Orla-Jensen) Bergey et al. (*Bacillus* γ, v. Freudenreich, Landw. Jahrb. d. Schweiz, 1891, 22; *Bacillus casei* γ, v. Freudenreich and Thöni, Landw. Jahrb. d. Schweiz, 1904, 526; also Orla-Jensen, Cent. f. Bakt., II Abt., *13*, 1904, 604; *Betabacterium breve* Orla-Jensen, The Lactic Acid Bacteria, 1919, 175; Bergey et al., Manual, 4th ed., 1934, 312.) From Latin *brevis*, short.

Probable synonyms: *Bacillus brassicae fermentatae* Henneberg, Ztschr. f. Spiritusindustrie, *26*, 1903; Cent. f. Bakt., II Abt., *11*, 1903, 167 (*Lactobacillus fermentatae* Bergey et al., Manual, 1st ed., 1923, 252); *Bacillus panis fermentati* Henneberg, Ztschr. f. Spiritusindustrie, *25*, 1903; Cent. f. Bakt., II Abt., *11*, 1903, 168 (*Lactobacillus panis* Bergey et al., Manual, 1st ed., 1923, 251); *Bacillus acidophil-aerogenes* Torrey and Rahe, Jour. Inf. Dis., *17*, 1915, 437 (*Lactobacillus acidophil-aerogenes*, Holland, Jour. Bact., *5*, 1920, 216); *Lactobacillus pentoaceticus* Fred, Peterson and Davenport, Jour. Biol. Chem., *39*, 1919, 357; Peterson and Fred, *ibid.*, *42*, 1920, 273; *Lactobacillus pentoaceticus* var. *magnus* Iwasaki, Jour. Agr. Chem. Soc. Japan, *16*, 1940, 148; *Lactobacillus lycopersici* Mickle, Abst. Bact., *8*, 1924, 403; Mickle and Breed, New York Agr. Exp. Sta. Tech. Bull. 110, 1925; Pederson, *ibid.*, Tech. Bull. 150 and 151, 1929; *Bacterium soya* Saito, Cent. f. Bakt., II Abt., *17*, 1907, 20 (*Lactobacillus soyae* Bergey et al., Manual, 1st ed., 1923, 251).

Bacillus caucasicus von Freudenreich, Cent. f. Bakt., II Abt., *3*, 1897, 135 and *Betabacterium caucasicum* Orla-Jensen, The Lactic Acid Bacteria, 1919, 173 were isolated from kefir grains and considered to be the organism Kern isolated in 1882. They are gas-producing lactobacilli but are less active toward sugars than *Lactobacillus brevis*.

Description supplemented by material from Pederson, Jour. of Bact., *35*, 1938, 105.

Rods: 0.7 to 1.0 by 2.0 to 4.0 microns, with rounded ends, occurring singly and in short chains, and occasionally in long filaments which may show granulation. Non-motile. Gram-positive.

Gelatin: No liquefaction.

Agar slant: Growth, if any, faint.

Broth: Turbid, clearing after a few days.

Milk: Acid produced but no clot except with some freshly isolated strains.

Does not attack casein as a rule.

Is able to utilize calcium lactate as a source of carbon.

Acid from arabinose, xylose, glucose, fructose, galactose and maltose. Strains vary in fermentation of lactose, sucrose, mannose and raffinose. Salicin, mannitol, glycerol, rhamnose, dextrin, inulin and starch seldom fermented. Usually shows a particularly vigorous fermentation of arabinose.

Lactic acid usually inactive; acetic acid, ethyl alcohol and carbon dioxide

formed in fermentation of aldohexoses. Mannitol produced from fructose. Acetic and lactic acid produced from the pentoses.

This species includes the large group of gas-producing lactic acid rods ordinarily characterized by a marked fermentation of pentoses, particularly arabinose. They usually also ferment fructose more readily than glucose.

Temperature relations: Optimum 30°C. Growth poor below 15° and above 37°C. Maximum 38°C.

Source: From milk, kefir, cheese, feces, fermenting sauerkraut, ensilage, manure, soils, sour dough, and spoiled tomato products.

Habitat: Widely distributed in nature, particularly in plant and animal products.

12a. *Lactobacillus brevis* var. *rudensis* Breed and Pederson. (*Lactobacillus rudensis* Davis and Mattick, Proc. Soc. Agr. Bact., 1936, 3 (this organism is presumably the same as *Bacillus rudensis* Davis and Mattick, Jour. Dairy Res., *1*, 1929, 50); Breed and Pederson (not Peterson), Jour. Bact., *36*, 1938, 667.) This chromogenic variety isolated from cheese is a causative agent in the production of rusty spot in cheese. From a study of cultures, it is regarded as a chromogenic variety of *Lactobacillus brevis*. See also species No. 10a.

13. **Lactobacillus buchneri** (Henneberg) Bergey et al. (*Bacillus buchneri* Henneberg, Cent. f. Bakt., II Abt., *11*, 1903, 163; Bergey et al., Manual, 1st ed., 1923, 251.) Named for Prof. E. Buchner, a German bacteriologist.

Probable synonyms: *Bacillus wehmeri* Henneberg, Cent. f. Bakt., II Abt., *11*, 1903, 165 (*Lactobacillus wehmeri* Bergey et al., Manual, 1st ed., 1923, 249); *Bacillus hayducki* Henneberg, Cent. f. Bakt., II Abt., *11*, 1903, 163 (*Lactobacillus hayduckii* Bergey et al., Manual, 1st ed., 1923, 253); *Bacterium mannitopoeum* Müller-Thurgau, Cent. f. Bakt., II Abt., *20*, 1908, 396; *ibid.*, *36*, 1912, 129; *ibid.*, *48*, 1917 (*Lactobacillus mannitopoeus* Pederson, New York Agr. Exp. Sta. Tech. Bull. 150 and 151, 1929; *Lactobacillus mannitopoeus* var. *fermentus* Iwasaki, Jour. Agr. Chem. Soc. Japan, *16*, 1940, 148).

Description supplemented by material from Pederson, Jour. Bact., *35*, 1938, 107.

Rods: 0.35 by 0.7 to 4.0 microns, occurring singly, in pairs and chains or in filaments 25 microns or longer. Non-motile. Gram-positive.

Agar colonies: White to yellowish, adherent.

Agar slant: Growth, if any, faint.

Broth: Turbid, clearing after a few days.

Litmus milk: Usually unchanged but may be slightly acid with no reduction.

Nitrites not produced from nitrates.

Acid usually from arabinose, xylose, glucose, fructose, galactose, mannose, sucrose, lactose, maltose and raffinose. Mannitol, sorbitol, glycerol, rhamnose, salicin, inulin, dextrin and starch fermented by a few strains.

Lactic acid usually inactive. Acetic acid, ethyl alcohol and carbon dioxide formed in the fermentation of aldohexoses. Mannitol produced from fructose. Acetic and lactic acid from pentoses.

Strains of this species might be considered intermediates between *Lactobacillus brevis* and *Lactobacillus fermenti*.

Forms 1.3 per cent lactic acid in mash and 2.7 per cent alcohol.

Optimum temperature 32° to 37°C. Minimum 10° to 15°C. Maximum 44° to 48°C.

Source: From sour mash, pressed yeast, molasses, wine, catsup and sauerkraut.

Habitat: Widely distributed in fermenting substances.

14. **Lactobacillus pastorianus** (Van Laer) Bergey et al. (*Saccharobacillus pastorianus* Van Laer, Cont. l'Histoire des Ferments des Hydrates de Carbone, Acad. Roy. de Belge, 1892; *Bacillus pastorianus* Macé, Traité Pratique de Bact.,

4th ed., 1901, 957; *Lactobacterium pastorianum* van Steenberge, Ann. Inst. Past., *34*, 1920, 816; Bergey et al., Manual, 1st ed., 1923, 246.) Named for Pasteur, French chemist; from Latin *pastor*, a herdsman.

Probable synonyms: *Saccharobacillus pastorianus* var. *berolinensis* Henneberg, Cent. f. Bakt., II Abt., *8*, 1902, 186 (*Lactobacillus berolinensis* Bergey et al., Manual, 1st ed., 1923, 246); *Bacillus lindneri* Henneberg, Wochnschr. f. Brauerei, *18*, 1901, No. 30; Cent. f. Bakt., II Abt., *8*, 1902, 184 (*Lactobacillus lindneri* Bergey et al., Manual, 1st ed., 1923, 245); *Bacillus fasciformis* Schönfeld and Rommel, Wochnschr. f. Brauerei, *19*, 1902, No. 40; abst. in Cent. f. Bakt., II Abt., *9*, 1902, 807 (*Saccharobacillus berolinensis fasciformis* Henneberg, Handb. der Gärungsbakteriologie, *2*, 1926, 123; *Bacillus belorinensis* (sic, evidently intended for *Bacillus berolinensis*) Otani, Cent. f. Bakt., II Abt., *101*, 1939, 149).

Description supplemented by material from Henneberg, Cent. f. Bakt., II Abt., *8*, 1902, 184; Shimwell, Jour. Inst. Brewing, *41*, 1935, 481; and Pederson, Jour. Bact., *35*, 1938, 107.

Rods: 0.5 to 1.0 by 7.0 to 35.0 microns, occurring singly and in chains. Non-motile. Gram-positive.

Gelatin colonies: No growth.

Beer wort gelatin stab: Beaded to arborescent growth.

Beer wort agar colonies: Small, gray, raised, filamentous.

Agar slant: Little or no growth; better in stab.

Broth: Good growth in yeast extract. Turbid.

Litmus milk: Acid.

Nitrites not produced from nitrates.

Acid from arabinose, glucose, fructose, galactose, maltose, sucrose, dextrin, raffinose, trehalose and mannitol and slightly from lactose and starch. No acid from xylose, rhamnose or inulin. Forms 1.5 per cent acid in mash. Also forms CO_2 and alcohol, lactic, formic and acetic acid.

The species includes the ordinarily long rod types from spoiled beers. Apparently the same variations in regard to sugar fermentation may be found as are noted for similar species.

Optimum temperature 29° to 33°C. Minimum 11°C. Maximum 37°C.

Microaerophilic.

Source: From sour beer and from distillery yeast.

Habitat: Probably more widely distributed than indicated by isolations.

15. **Lactobacillus fermenti** Beijerinck. (Beijerinck, Arch. néerl. d. sci. exactes et nat., Sér. *2*, 7, 1901, 212; Smit, Ztschr. f. Gärungsphysiol., *5*, 1916, 273; *Lactobacterium fermentum* van Steenberge, Ann. Inst. Past., *34*, 1920, 816.) From Latin *fermentum*, ferment, yeast.

Probable synonyms: *Bacillus δ*, von Freudenreich, Cent. f. Bakt., II Abt., 1, 1895, 173; also Landw. Jahrb. d. Schweiz, 1895, 211; *Bacillus casei δ*, von Freudenreich and Thöni, Landw. Jahrb. d. Schweiz, 1904, 526; also Orla-Jensen, Cent. f. Bakt., II Abt., *13*, 1904, 609; *Betabacterium longum* Orla-Jensen, The Lactic Acid Bacteria, 1919, 174 (*Lactobacillus longus* Bergey et al., Manual, 4th ed., 1934, 312); *Bacterium gayonii* Müller-Thurgau and Osterwalder, Cent. f. Bakt., II Abt., *48*, 1917, 1 (*Lactobacillus gayonii* Pederson, New York Agr. Exp. Sta. Tech. Bull. 150 and 151, 1929); *Bacterium intermedium* Müller-Thurgau and Osterwalder, Cent. f. Bakt., II Abt., *48*, 1917, 1 (*Lactobacillus intermedium* Bergey et al., Manual, 3rd ed., 1930, 295); *Bacillus aderholdi* Henneberg, Cent. f. Bakt., II Abt., *11*, 1903, 166.

Description supplemented by material from Pederson, Jour. Bact., *35*, 1938, 106.

Rods: Variable, usually short (Beijerinck), 0.5 to 1.0 by 3.0 to 15.0 microns (Smit), sometimes in pairs or chains. Non-motile. Gram-positive (Smit).

Yeast extract-glucose-gelatin: Filiform, no liquefaction (Pederson).

Agar colonies: Flat, circular, small, translucent like droplets of water.

Agar slant: Growth, if any, scant.

Broth: Turbid, clearing after a few days.

Milk: Unchanged or slightly acid.

Nitrites not produced from nitrates.

Reduction of litmus, methylene blue, indigo carmine, sodium thiosulfate. Na_2SO_3 is reduced to H_2S (Smit).

Acid usually from glucose, fructose, maltose, sucrose and lactose (Beijerinck) and mannose, galactose, and raffinose; some strains ferment xylose; usually does not ferment arabinose, rhamnose, sorbitol, mannitol, inulin, dextrin, starch or salicin (Pederson).

Lactic acid, usually inactive; acetic acid, ethyl alcohol and carbon dioxide are formed in the fermentation of aldehexoses (Smit), (Pederson). Mannitol is formed in the fermentation of fructose (Beijerinck), (Smit). Acetic acid and lactic acid are produced from pentoses if they are fermented (Pederson).

These are the higher temperature gas-producing rods. They usually do not ferment the pentoses but when they do, the fermentation is seldom as active as that produced by strains of *Lactobacillus brevis*.

Temperature relations: Optimum 41° to 42°C. Minimum 15° to 18°C. Maximum 48° to 50°C.

Microaerophilic.

Source: From yeast, milk products, fermenting dough, potatoes or vegetables, tomato products and wine.

Habitat: Widely distributed in nature, particularly in fermenting plant or animal products.

Appendix I:* The following species probably should be included in the genus *Lactobacillus*. Many are duplicates of the species described in full, but the majority are so poorly characterized that they cannot be properly identified.

Acidobacterium aerogenes Schlirf. (Stäbchen Ka, Heim, Cent. f. Bakt., I Abt., Orig., *93*, 1924, 252; Schlirf, Cent. f. Bakt., I Abt., Orig., *97*, 1925, 114; *Plocamobacterium aerogenes* Lehmann, in Lehmann and Neumann, Bakt. Diag., 7 Aufl., *2*, 1927, 509.) Possibly *Lactobacillus brevis* Bergey et al. Produces acid and gas from glucose. From dental caries, mouth cavity and intestine.

Acidobacterium lactis Heim. (Heim, quoted from Schlirf, Cent. f. Bakt., I Abt., Orig., *97*, 1925, 113.) Schlirf says that this species is probably identical with *Bacillus necrodentalis* Goadby. Regarded by Lehmann (in Lehmann and Neumann, Bakt. Diag., 7 Aufl., *2*, 1927, 507–508) as identical with *Bacillus acidophilus* Moro; or it may be identical with *Streptobacterium casei* Orla-Jensen. From dental caries, deposit on tongue and in intestine.

Acidobacterium moroi Schlirf. (Stäbchen Kc, Heim, Cent. f. Bakt., I Abt., Orig., *93*, 1924, 252; Schlirf, Cent. f Bakt., I Abt., Orig., *97*, 1925, 114 *Plocamobacterium moroi* Lehmann, in Lehmann and Neumann, Bakt. Diag., 7 Aufl., *2*, 1927, 508.) From the intestine. Similar to *Acidobacterium lactis*. Kuchinka (Cent. f. Bakt., I Abt., Orig., *144*, 1939, 370) reports this organism as occurring in two cases of meningitis.

Bacillus bifidus aerobius Heurlin. (Bakt. Unters. d. Keimgehaltes im Genitalkanale d. fiebernden Wöchnerinnen. Helsinfors, 1910, 93.) From the genital canal. Resembles *Bacillus bifidus communis* Tissier.

Bacillus bifidus capitatus Heurlin. (Bakt. Unters. d. Keimgehaltes im Genitalkanale d. fiebernden Wöchnerinnen. Helsingfors, 1910, 175.) From the genital canal.

Bacillus carpathiens Kindraizuk. (Oesterr. Molkerei Zeit., *29*, 1912, 257.)

* Arranged by Prof. C. S. Pederson, New York State Experiment Station, Geneva, New York, March, 1945.

From the sour milk of the Carpathian region. Presumably *Lactobacillus bulgaricus*.

Bacillus circularis minor Heurlin. (Bakt. Unters. d. Keimgehaltes im Genitalkanale d. fiebernden Wöchnerinnen. Helsingfors, 1910, 170.) From the genital canal. Anaerobic.

Bacillus necrodentalis Goadby. (Goadby, Microorganisms in dental caries, Dental Cosmos, *42*, 1900, 213.) From dental caries.

Bacillus orenburgii Horowitz-Wlassowa. (Cent. f. Bakt., II Abt., *64*, 1925, 338.) From kumys (Caucasus). Presumably *Lactobacillus bulgaricus*.

Bacillus orientale Batchinsky. (Batchinsky, Arch. d. Gesellsch. d. Naturf. St. Petersburg, *42*, 1911; quoted from Horowitz-Wlassowa, Cent. f. Bakt., II Abt., *64*, 1925, 330.) From kumys in Ufa (U.S.S.R.). Presumably *Lactobacillus bulgaricus*.

Bacillus sardous Grixoni. (Annali di Med. Navale, *112*, 1905, 223 and Cent. f. Bakt., II Abt., *15*, 1905, 951; *Bacterium sardum miciurati* Bianco, Il Cesalpino, *8*, 1912, 33.) From gioddu (Sardinia). Presumably *Lactobacillus bulgaricus*.

Bacillus vaginae Kruse. (Scheidenbacillen, Doederlein, Das Scheidensekret und seine Bedeutung für das Puerperalfieber, Leipzig, 1892, 32; Kruse, in Flügge, Die Mikroorganismen, 3 Aufl., *2*, 1896, 358; *Bacillus vaginalis longus* Heurlin, Bakt. Unters. d. Keimgehaltes im Genitalkanale d. fiebernden Wöchnerinnen. Helsingsfors, 1910, 170; *Bacillus vaginalis* Jotten, Arch. f. Hyg., *91*, 1922, 149; Stäbchen Ke, Heim, Cent. f. Bakt., I Abt., Orig., *93*, 1924, 252; *Acidobacterium doederleinii* Heim, quoted from Schlirf, Cent. f. Bakt., I Abt., Orig., *97*, 1925, 104; *Plocamobacterium vaginae* Lehmann, in Lehmann and Neumann, Bakt. Diag., 7 Aufl., *2*, 1927, 510; *Lactobacillus doederlein* Gillespie and Rettger, Jour. Bact., *36*, 1938, 623.) Kruse (Allgemeine Mikrobiol., 1910, 287) considers this species a "langen Milchsäurebacillus" all of which he would group under the name *Bacillus lacticus* (not *Bacillus lacticus* Kruse, in Flügge, Die Mikroorganismen, 3 Aufl., *2*, 1896, 356 as this is *Streptococcus lactis* Löhnis). Jotten (*loc. cit.*) and Thomas (Jour. Inf. Dis., *43*, 1928, 218) consider this species identical with *Lactobacillus acidophilus* (Moro) Holland. From the secretion of the normal vagina. See *Bacillus crassus* Lipschütz.

Bacterium gracile Müller-Thurgau. (Cent. f. Bakt., II Abt., *20*, 1908, 396; Müller-Thurgau and Osterwalder, *ibid.*, *36*, 1912, 157; *ibid.*, *48*, 1917, 1; *Lactobacillus gracile* Bergey et al., Manual, 3rd ed., 1930, 297.) This organism which was isolated from wine is probably not a lactobacillus. It may belong to the genus *Leuconostoc* (subculture examined in 1936, C. S. Pederson).

Bacterium granulosum Lehmann and Neumann. (Körnchenbacillus, Luerssen and Kühn, Cent. f. Bakt., II Abt., *20*, 1907, 241; Lehmann and Neumann, Bakt. Diag., 5 Aufl., *2*, 1912, 306.) From yoghurt (Bulgaria). Presumably *Lactobacillus bulgaricus*.

Bacterium lactis commune Hohennadel. (Arch. f. Hyg., *85*, 1916, 237.) From feces. Similar to *Lactobacillus acidophilus* (Moro) Holland.

Bacterium mazun Weigmann, Gruber and Huss. (Milchsäurebakterium aus Mazun, Düggeli, Cent. f. Bakt., II Abt., *15*, 1905, 595; Weigmann et al., Cent. f. Bakt., II Abt., *19*, 1907, 78.) From mazun (Armenia). Presumably *Lactobacillus bulgaricus*.

Bacterium vermiforme Ward. (Phil. Tran. Roy. Soc. London, *183*, 1892, 149; *Bacillus vermiformis* Migula, Syst. d. Bakt., *2*, 1900, 652; *Betabacterium vermiforme* Mayer, Inaug. Diss., Univ. Utrecht, 1938.) Originally isolated from the ginger beer plant fermentation. This is presumably a slime-forming lactobacillus.

Bacteroides aerofaciens Eggerth and *Bacteroides biformis* Eggerth. (Jour. Bact., *30*, 1935, 282–283.) From feces. Possibly lactobacilli but their relationships are not definitely known.

Lactobacillus betadelbrueckii Kitahara. (Bull. Agr. Chem. Soc. Japan, Tokyo, *16*, 1940, 123.) From cereal mash.

Lactobacillus caneus Kitahara (*loc. cit.*). From cereal mash.

Lactobacillus ciliatus Kitahara (*loc. cit.*). From cereal mash.

Lactobacillus enzymothermophilus Buck. (Amer. Jour. Pub. Health, *32*, 1942, 1230.) A thermophilic (growth at 52° and 62°C) presumably spore-forming bacillus isolated from pasteurized milk.

Lactobacillus fructovorans Charlton, Nelson and Werkman. (Iowa State Coll. Jour. Sci., *9*, 1934, 1.) From salad dressing. Similar to *Lactobacillus brevis*.

Lactobacillus hilgardii Douglas and Cruess. (Food Research, *1*, 1936, 113.) This organism was isolated from wine but is not completely described and so cannot be compared with previously described species.

Lactobacillus hyochi Otani, *Lactobacillus hyochi* var. 1, Otani, *Lactobacillus hyochi* var. 2, Otani, *Lactobacillus filamentosus* Otani, *Lactobacillus alcoholphilus* Otani, and *Lactobacillus saprogenes* Otani. (Jour. Faculty of Agric., Hokkaido Imp. Univ., *39*, 1936, 2.) These organisms were isolated from sake. With the possible exception of the last type, they are probably identical with *Lactobacillus plantarum* or closely related species.

Lactobacillus odontolyticus Rodriguez. (*Bacillus acidophilus odontolyticus I* and *II*, McIntosh, James and Lazarus-Barlow, Brit. Jour. Exp. Med. and Path., *3*, 1922, 141; *Bacillus acidophilus odontolyticus*, *ibid.*, 145; *Lactobacillus odontolyticus* and *Lactobacillus odontolyticus* Types *I*, *II* and *III*, Rodriguez, Military Dent. Jour., *5*, 1922, 206; *Bacillus odontolyticus* McIntosh, James and Lazarus-Barlow, Brit. Jour. Exp. Med. and Path., *5*, 1924, 178; *Bacillus acidophilus-odontolyticus* Rosebury, Linton and Buchbinder, Jour. Bact., *18*, 1929, 395; *Lactobacillus odontolyticus I* and *II*, Topley and Wilson, Princ. Bact. and Immun., 2nd ed., 1936, 588.) From dental caries. Type I resembles and is possibly identical with *Bacillus acidophilus* Moro and Doederlein's bacillus (*Bacillus vaginae* Kruse). See Rosebury, Bact. Rev., *8*, 1944, 189 and Arch. of Path., *38*, 1944, 413. Type II shows considerable pleomorphism, short coccal forms appearing in the more alkaline media (McIntosh, James and Lazarus-Barlow, Brit. Jour. Exp. Med. and Path., *5*, 1924, 183). Types I, II and III of Rodriguez (*loc. cit.*) do not correspond with Types I and II of McIntosh et al. or with the groupings of Howe and Hatch (Jour. Med. Res., *36*, 1917, 481).

Lactobacillus panis acidi Nikolaev. (Wiss. Forschungsinst. Bäkerei-indust., U. S. S. R., *5*, 1933, 3–11.) Four isolations from bread dough designated by the Greek letters, α, β, γ_1 and γ_2.

Lactobacillus sake Katagiri, Kitahara, Fukami and Sugase. (Bull. Agric. Chem. Soc. Japan, *10*, 1934, 153.) From mash used in the manufacture of sake. Similar to *Lactobacillus plantarum*.

Lactobacillus xylosus Kitahara. (Bull. Agr. Chem. Soc. Japan, Tokyo, *16*, 1940, 123.) From cereal mash.

Lactobacterium cerevisiae van Steenberge. (Ann. Inst. Past., *34*, 1920, 806.) From beer.

Lactobacterium conglomeratum van Steenberge (*loc. cit.*, 812). From beer-wort.

Lactobacterium filatim van Steenberge (*loc. cit.*, 812). From beer-wort.

Lactobacterium floccogenum van Steenberge (*loc. cit.*, 812). From beer-wort.

Lactobacterium grave van Steenberge (*loc. cit.*, 814). From beer-wort.

Lactobacterium multivolaticum van Steenberge (*loc. cit.*, 814). From beer-wort.

Lactobacterium multivolatigenum van Steenberge (*loc. cit.*, 812). From beer-wort.

Lactobacterium oligoacidificans van Steenberge, (*loc. cit.*, 814). From beer-wort.

Lactobacterium parcifermentans van Steenberge (*loc. cit.*, 812). From beer-wort.

Lactobacterium terricola van Steenberge (*loc. cit.*, 806). From garden soil.

Lactobacterium viscogenum van Steenberge (*loc. cit.*, 814). From beer-wort.

Streptobacillus lebenis Rist and Khoury. (Rist and Khoury, Ann. Inst. Past., *16*, 1902, 70; *Bacillus lebeni* Kuntze, Cent. f. Bakt., II Abt., *21*, 1908, 744; *Streptobacillus lebensis* α and β Löhnis, Cent. f. Bakt., II Abt., *22*, 1909, 553; *Streptobacillus lebenis viscosus* and *Streptobacillus lebenis nonviscosus* Severin, Cent. f. Bakt., II Abt., *24*, 1909, 488; *Bacterium lebenis* Lehmann and Neumann, Bakt. Diag., 5 Aufl., *2*, 1912, 308.) From leben (Egypt and Near East). Presumably *Lactobacillus bulgaricus.*

Streptothrix dadhi Chatterjee. (Cent. f. Bakt., I Abt., Orig., *53*, 1910, 111.) From sour milk (dadhi) of India. Presumably *Lactobacillus bulgaricus.*

Thermobacterium jugurt Orla-Jensen. (Yoghurt bakterium, Kuntze, Cent. f. Bakt., II Abt., *21*, 1908, 737; Orla-Jensen, The Lactic Acid Bacteria, 1919, 164; *Lactobacillus jugurt* Holland, Jour. Bact., *5*, 1920, 225.) From jughurt (Bulgaria). Presumably *Lactobacillus bulgaricus.*

Thermobacterium mathiacolle Cecilia. (Le Lait, *20*, 1940, 385–390.) From sweetened condensed milk. Possibly a spore-former.

Appendix II:* The genus *Leptotrichia* Trevisan, 1879 is no longer recognized as a valid genus. While the confusion with *Leptothrix* Kützing, 1843 was corrected by Trevisan's work, the identity of the type species, *Leptotrichia buccalis*, is uncertain. Few of the species that have been placed in *Leptothrix* and *Leptotrichia* are well enough described to be recognized with certainty.

All descriptions of *Leptotrichia buccalis* published earlier than 1886 are based on microscopic observations only. This is also true of the three species of *Leptothrix* recognized by Miller (Die Mikroorganismen der Mundhöhle, Leipzig, 1889, 69–80). The species that he distinguished in this way are recognized in the seven editions of Lehmann and Neumann's Bakteriologische Diagnostik published from 1896 to 1927. Chester (Manual Determ. Bact., 1901, 371) also follows Miller's ideas in regard to the nature of the species of *Leptothrix.* These authors felt that the identity of the true *Leptotrichia buccalis* was doubtful.

On the other hand, Vignal (Arch. de Physiol. norm. et path., *8*, 1886, 337) isolated what he thought to be this organism, and it is his description that is used with minor changes by Eisenberg (Bakt. Diag., 3 Aufl., 1891, 134), Migula (Syst. d. Bakt., *2*, 1900, 445) and in all editions of Bergey's Manual (1923–1939) up to the present edition. A study of Vignal's work shows, however, that the filamentous organism that he isolated and grew readily in broth, agar and gelatin cultures was in all probability one of the common spore-formers. It grew but rarely on the plates inoculated with material from the mouth. As is clearly shown in his drawing and descriptions, it liquefied gelatin rather quickly with the formation of the characteristic wrinkled pellicle of a spore-former. Soon after, Arustamow (Wratsch, 1889, Nos. 3 and 4; abstract in Cent. f. Bakt., *6*, 1889, 349) isolated a similar aerobic, filamentous organism that grew readily at 37°C on agar and gelatin, but he also noted large numbers of very tiny colonies of a microaerophilic bacterium which may have been the lactobacilli or lactobacilli-like organisms of later authors. Even recent excellent reviews of the

* Completely rearranged by Prof. Robert S. Breed and Prof. Carl S. Pederson, New York State Experiment Station, Geneva, New York, March, 1945.

early literature (Buchanan, Systematic Bact., 1925, 345–353; Thjøtta, Hartmann and Bøe, Norske Videnkaps Akad. i Oslo, I, Math.-Nat. Klasse, No. 5, 1939, 41 pp.) or reviews of the voluminous studies of the past thirty years (Rosebury, Bact. Rev., *8*, 1944, 198) fail to clear away all of the confusion that has arisen.

Some investigators, such as Heim (Sitzber. d. physik.-med. Soz. in Erlangen for 1922–23, *54*, 1925, 121) and his co-workers, grew the mouth streptococci readily and thought them important as the cause of dental caries. Others following the lead of Kligler (Jour. Allied Dental Soc., *10*, 1915, 282 and 445) and Wherry and Oliver (Jour. Inf. Dis., *19*, 1916, 299) have found the most important organisms of caries to be the long, Gram-positive, granular, non-motile rods that grow like lactobacilli. But even here it is not altogether clear whether the high acid-producing (*Bacillus acidophilus odontolyticus* McIntosh, James and Lazarus-Barlow, British Jour. Exper. Path., *3*, 1922, 145) or the low acid-producing type (*Leptothrichia buccalis* Thjøtta et al., *loc. cit.*, 31) of rods really represents the *Leptothrix buccalis* of early observers. Some observers, e. g., Balleid (Brit. Dent. Jour., *48*, 1925, 289), have even identified a branching organism of the mouth, *Actinomyces israeli*, as *Leptotrichia buccalis* according to Rosebury (*loc. cit.*, 200).

As these mouth organisms are apparently better placed in other genera so far as they have been definitely identified, the genus and the species that have been described as belonging in it are merely listed here.

Genus A. **Leptotrichia** *Trevisan.*

(Trevisan, Reale Istituto Lombardo di Scienze e Lettere, Ser. II, *4*, 1879, 147; not *Leptothrix* Kützing, Phycologica Generalis, 1843, 198; *Bacteriopsis* Trevisan, Atti della Accad. Fisio-Medico-Statistica in Milano, Ser. IV, *3*, 1885, 103; *Rasmussenia* De Toni and Trevisan, in Saccardo, Sylloge Fungorum, *8*, 1889, 930; *Syncrotis* Enderlein, Sitzber. Gesell. Naturf. Freunde, Berlin, 1917, 312.)

The type species is *Leptotrichia buccalis* (Robin) Trevisan.

Leptotrichia buccalis (Robin) Trevisan. (*Leptothrix buccalis* Robin, Histoire naturelle des végétaux parasites, Paris, 1853, 354; Trevisan, Reale Istituto Lombardo di Scienze e Lettere, Ser. II, *4*, 1879, 147; *Leptothrix III*, Rasmussen, Om Dryckning of Microorganismer fra Spyt of sunde Mannesker, 1883; *Rasmussenia buccalis* De Toni and Trevisan, in Saccardo, Sylloge Fungorum, *8*, 1889, 930; *Bacterium buccale* Migula, Syst. d. Bakt., *2*, 1900, 445; not *Leptothrix buccalis* Chester, Manual Determ. Bakt., 1901, 371; not *Bacillus buccalis* Chester, *ibid.*, 234; not *Bacillus buccalis* Trevisan, I generi e le specie delle Batteriacee, 1889, 15; *Syncrotis buccalis* Enderlein, Sitzungsber. Ges. Naturf. Freunde, Berlin, 1917, 312; *Bacillus buccalis* Holland, Jour. Bact., *5*, 1920, 217.) From the mouth.

Other species that have been associated with this genus are as follows:

Bacillus maximus buccalis Miller. (Deutsche med. Wchnschr., *14*, 1888, 612; *Bacillus buccalis* Trevisan, I generi e le specie delle Batteriacee, 1889, 15) From the mouth. Regarded by Goadby (The Mycology of the Mouth, London, 1903) and by Kligler (Jour. Allied Dental Soc., *10*, 1915, 152) as a spore-former.

Leptothrix asteroide Mendel. (Compt. rend. Soc. Biol., Paris, *81*, 1918, 471–475.) From the mouth. Rosebury (Bact. Rev., *8*, 1944, 202) thinks this Gram-negative, anaerobic organism belongs in *Bacteroides* Castellani and Chalmers.

Leptothrix anaerobius tenuis Lewkowicz. (Arch. méd. exp. anat. path., *13*, 1901, 633; *Leptothrix tenuis* Weinberg et al., Les Microbes Anaérobies, 1937, 844; *Pseudoleptothrix tenuis* Prévot, Ann. Inst. Past., *60*, 1938, 301.) From mouths of infants.

Leptothrix falciformis Beust. (Dental Cosmos, *50*, 1908, 594; Jour. Dent. Res., *16*, 1937, 379.) From the mouth.

Leptothrix filiformis Castellani and Chalmers. (*Bacillus* (*Leptothrix?*) *pyogenes filiformis* Flexner, Jour. Exp. Med., *1*, 1896, 211; Castellani and Chalmers, Man. Trop. Med., 3rd ed., 1919, 1068.) From the genital tract and thoracic cavities of a rabbit with an acute pleuritis, pericarditis, pneumonia and acute endometritis. Gram-negative. Not regarded as identical with *Bacillus piliformis* Tyzzer (Jour. Med. Res., *37*, 1917, 307) which is a spore-former.

Leptothrix gigantea Miller. (Miller, Ber. d. deutsch. bot. Gesell., *1*, 1883, 221; *Leptotrichia gigantea* Trevisan, I generi e le specie delle Batteriacee, 1889, 10; *Rasmussenia gigantea* De Toni and Trevisan, in Saccardo, Sylloge Fungorum, *8*, 1889, 930.) From pyorrhœa in dogs, swine and sheep. This name was applied to a mixture of species.

Leptothrix haemoglobinophila sporulens Mackenzie. (In System of Bact., Med. Res. Council, London, *8*, 1931, 99.) From cerebro-spinal fluid. A Gram-negative spore-former.

Leptothrix innominata Miller. (Die Mikroorganismen der Mundhöhle, 1889, 51, Leipzig; *Pseudoleptothrix innominata* Prévot, Ann. Inst. Past., *60*, 1938, 301.) Prévot (*loc. cit.*) regards this species as type for his new genus *Pseudoleptothrix*. Proposed to include all filamentous forms from the mouth that resemble *Leptothrix buccalis* Robin.

Leptothrix insectorum Robin. (Histoire naturelle der végétaux parasites, Paris, 1853, 354.) From the rectums of insects.

Leptothrix maxima buccalis Miller. (Miller, Deutsche med. Wchnschr., *14*, 1888, 612; *Leptotrichia maxima* Trevisan, I generi e le specie delle Batteriacee, 1889, 10; *Rasmussenia maxima* De Toni and Trevisan, in Saccardo, Sylloge Fungorum, *8*, 1889, 930; *Leptothrix buccalis* Chester, Man. Determ. Bact., 1901, 371; *Bacillus maximus* Goadby, Mycology of the Mouth, 1903, 191.) From the mouth.

Leptothrix parasitica Kützing. (Kützing, Bot. Zeitg., 1847, 220; quoted from Winter, in Die Pilze, Rabenhorst's Kryptogamen Flora, 2 Aufl., *1*, 1880, 57; *Bacterium parasiticum* Billet, Bull. Sci. de la France et de la Belgique, Paris, *21*, 1890, 199.) From a brownish deposit on algae.

Leptothrix preputialis Vicentini. (Atti Accad. Med. Chir. di Napoli, *43*, 1890–91, quoted from Vicentini, Bacteria of the Sputa. Trans. by Stuter and Saieghi, London, 1897, 89.) From the urethra.

Leptothrix pyogenes cuniculi Muscatello. (Muscatello, 1899, quoted from Nannizzi, in Pollacci, Tratt. Micopat. Umana, *4*, 1934, 57; *Leptotrichia cunieuli* (sic) Nannizzi, *ibid.*, 57.) From spontaneous suppuration in a rabbit.

Leptothrix racemosa Vicentini. (Vicentini, Atti d. r. Accad. Med.-Chir. di Napoli, *46*, 1892, 459; *Leptotrichia racemosa* Nannizzi, in Pollacci, Tratt. Micopat. Umana, *4*, 1934, 56.) From the mouth. Conidia-like bodies are described. See Vicentini, Bact. of the Sputa, Eng. Trans. by Stuter and Saieghi, London, 1897 and Williams, Dental Cosmos, *41*, 1899, 330.

Leptothrix racemosa vincenti (sic) Mackenzie. (Leptothrix, Matthews, Pract., *74*, 1905, 197; Mackenzie, in System of Bact., Med. Res. Council, London, *8*, 1931, 94.) From localized empyema. Appears to be the same as Vicentini's organism.

Leptothrix vaginalis Donné. (Donné, quoted from Nannizzi, in Pollacci, Tratt. Micopat. Umana, *4*, 1934, 56; *Leptotrichia vaginalis* Nannizzi, *ibid.*, 56.) Saprophyte from the vagina.

Leptothrix vaginalis von Herff. (Ueber Scheidenmykosen, Samml. klin. Vortr. n. F., 1895, No. 137.) From a case of vaginal mycosis.

Leptothrix variabilis Rasmussen. (Rasmussen, Om Dryckning of Microorganismer fra Spyt of sunde Mannesker,

1883; *Leptothrix II*, Zopf, Die Spaltpilze, 3 Aufl., 1885, 107; *Leptotrichia variabilis* Trevisan, I generi e le specie delle Batteriacae, 1889, 10; *Rasmussenia variabilis* De Toni and Trevisan, in Saccardo, Sylloge Fungorum, *8*, 1889, 931.) From saliva.

Rasmussenia anceps De Toni and Trevisan. (*Leptothrix I*, Rasmussen, Om Dryckning of Microorganismer fra Spyt of sunde Mannesker, 1883; *Bacteriopsis rasmusseni* Trevisan, Atti della Accad. Fisio-Med.-Stat. in Milano, Ser. IV, *3*, 1885, 103; *Bacillus rasmusseni* Trevisan, I generi e le specie delle Batteriacee, 1889, 15; De Toni and Trevisan, in Saccardo, Sylloge Fungorum, *8*, 1889, 930; *Leptotrichia anceps* Nannizzi, in Pollacci, Tratt. Micopat. Umana, *4*, 1934, 54.) From saliva.

Appendix III:* Many species of anaerobic, Gram-positive, non-spore-forming, largely parasitic rods have been described. These are similar in many ways to the species included in *Lactobacillus*. Prévot has arranged these in the following genera. Several are inadequately studied and scarcely deserve recognition. Some, as indicated, may belong in other genera, e.g., spore-formers belonging in genus *Clostridium*. Some species produce gas in sugar broths or have other characteristics (e.g., motility) that are unusual for the families that include Gram-positive, non-spore-forming rods.

Genus I. **Eubacterium** *Prévot*
(Ann. Inst. Past., *60*, 1938, 294.)

Non-motile, straight or curved rods. Usually occurring singly, in pairs or very short chains. Never show branching. Not capsulated. Gram-positive. Anaerobic.

1. *Eubacterium foedans* (Klein) Prévot. (*Bacillus foedans* Klein, Lancet, *1*, 1908, 1832; Prévot, Ann. Inst. Past., *60*, 1938, 294.) From salted ham.

2. *Eubacterium niosii* (Hauduroy et al.) Prévot. (Anaerobe Bacillus, Niosi, Cent. f. Bakt., I Abt., Orig., *58*, 1911, 193; *Bacteroides niosii* Hauduroy et al., Dict. d. Bact. Path., 1937, 65; Prévot, Ann. Inst. Past., *60*, 1938, 294.) From suppurative pleuritis.

3. *Eubacterium rectale* Prévot. (Un bacille anaérobie, Grooten, Compt. rend. Soc. Biol., Paris, *102*, 1929, 43; *Bacteroides rectalis* Hauduroy et al., Dict. d. Bact. Path., 1927, 72; Prévot, Ann. Inst. Past., *60*, 1938, 294.) From rectal ulcer.

4. *Eubacterium obsti* Prévot. (Bacillus B, Obst, Jour. Inf. Dis., *24*, 1919, 159 and 168; Prévot, Ann. Inst. Past., *60*, 1938, 294.) From stomach of sardines and from their food (small crustaceans).

5. *Eubacterium quartum* Prévot. (Anaerob No. IV, Rodella, Ztschr. f. Hyg., *41*, 1902, 474; Prévot. Ann. Inst. Past., *60*, 1938, 294.) From intestine of a child.

6. *Eubacterium quintum* Prévot. (Anaerob No. V, Rodella, Ztschr. f. Hyg., *41*, 1902, 475; Prévot, Man. de Class. et Determ., Monographie Inst. Past., 1940, 65.) From intestine of a child.

7. *Eubacterium ethylicum* Prévot. (*Bacillus gracilis ethylicus* Achalme and Rosenthal, Compt. rend. Soc. Biol., Paris, *57*, 1906, 1025; Prévot, Ann. Inst. Past., *60*, 1938, 295.) From a human stomach.

8. *Eubacterium cadaveris* Prévot (see *Bacillus cadaveris butyricus* Buday). No spores observed.

9. *Eubacterium tortuosum* (Debono) Prévot. (*Bacillus tortuosus* Debono, Cent. f. Bakt., I Abt., Orig., *62*, 1912, 233; *Bacteroides tortuosus* Bergey et al., Manual, 1st ed., 1923, 529; Prévot, Ann.

* Arranged by Prof. Robert S. Breed, New York State Experiment Station, Geneva, New York, March, 1945.

Inst. Past., *60*, 1938, 295.) From human feces.

10. *Eubacterium aerofaciens* (Eggerth) Prévot. (*Bacteroides aerofaciens* Eggerth, Jour. Bact., *30*, 1935, 282; Prévot, Ann. Inst. Past., *60*, 1938, 295.) From human feces.

11. *Eubacterium biforme* (Eggerth) Prévot. (*Bacteroides biformis* Eggerth, Jour. Bact., *30*, 1935, 283; Prévot, Ann. Inst. Past., *60*, 1938, 295.) From human feces.

12. *Eubacterium limosum* (Eggerth) Prévot. (*Bacteroides limosus* Eggerth, Jour. Bact., *30*, 1935, 290; Prévot, Ann. Inst. Past., *60*, 1938, 295.) From human feces. Pederson (Jour. Bact., *50*, 1945, 478) secured a culture of this species from Eggerth, and found that it fermented glucose with the production of higher fatty (presumably butyric) acids and lactic acid. The species should probably be placed in *Butyribacterium* Barker.

13. *Eubacterium disciformans* (Massini) Prévot. (*Bacillus disciformans* Massini, Ztschr. f. gesammte Exp. Med., *2*, 1913, 81; Prévot, Ann. Inst. Past., *60*, 1938, 295.) From respiratory system and skin.

14. *Eubacterium poeciloides* (Roger and Garnier) Prévot. (*Bacillus poeciloides* Roger and Garnier, Bull. et Mem. Soc. Méd. des Hôpitaux Paris, *2*, 1906, 870; Prévot, Ann. Inst. Past., *60*, 1938, 295.) From intestine.

15. *Eubacterium typhi exanthematici* Prévot (see *Corynebacterium typhi* Topley and Wilson).

17. *Eubacterium minutum* (Tissier) Prévot. (*Bacillus anaerobicus minutus* Tissier, Recherches sur la flore intestinale des nourissons, Paris, 1900; *Bacteroides minutus* Hauduroy et al., Dict. d. Bact. Path., 1937, 64; Prévot, Ann. Inst. Past., *60*, 1938, 295.) From intestine of breast-fed infant.

18. *Eubacterium parvum* (Choukévitch) Prévot. (*Coccobacillus anaerobicus parvus* Choukévitch, Ann. Inst. Past., *25*, 1911, 256; Prévot, Ann. Inst. Past., *60*, 1938, 295.) From large intestine of a horse.

19. *Eubacterium lentum* (Eggerth) Prévot. (*Bacteroides lentus* Eggerth, Jour. Bact., *30*, 1935, 280; Prévot, Ann. Inst. Past., *60*, 1938, 295.) From human feces.

Genus II. **Catenabacterium** *Prévot.*
(Ann. Inst. Past., *60*, 1938, 294.)

Non-motile, straight or curved rods. Usually grow in long chains or filaments. No branching. Not capsulated. Gram-positive. Anaerobic.

1. *Catenabacterium helminthoides* (Lewkowicz) Prévot. (*Bacillus helminthoides* Lewkowicz, Arch. de Méd. Exp., *13*, 1901, 631; Prévot, Ann. Inst. Past., *60*, 1938, 295.) From mouth of breast-fed infant.

2. *Catenabacterium filamentosum* Prévot. (Jungano, Compt. rend. Soc. Biol., Paris, *60*, 1909, 112 and 122; Prévot, Ann. Inst. Past., *60*, 1938, 295.) From intestine of a rat.

3. *Catenabacterium lottii* Prévot. (Lotti, Ann. Ig. Sper., *19*, 1909, 75; Prévot, Ann. Inst. Past., *60*, 1938, 296.) From human appendix and intestine.

4. *Catenabacterium catenaforme* (Eggerth) Prévot. (*Bacteroides catenaformis* Eggerth, Jour. Bact., *30*, 1935, 286; Prévot, Ann. Inst. Past., *60*, 1938, 296.) From human feces.

5. *Catenabacterium nigrum* (Repaci) Prévot. (*Streptobacillus gangrenae pulmonaris* Repaci, Compt. rend. Soc. Biol., Paris, *61*, 1910, 410; Prévot, Ann. Inst. Past., *60*, 1938, 296.) From gangrenous tissue found in a lung.

Genus III. **Ramibacterium** *Prévot.*
(Ann. Inst. Past., *60*, 1938, 294.)

Non-motile, straight or curved rods with frequent branching. Not capsulated. Gram-positive. Anaerobic.

1. *Ramibacterium ramosum* (Veillon and Zuber) Prévot. (*Bacillus ramosus* Veillon and Zuber, Arch. méd. exp. et anat. path., *10*, 1898, 542; *Nocardia ramosa* Vuillemin, Encyclopédie Mycolog., Paris, *2*, Champignons Parasites, 1931, 132; *Actinomyces ramosus* Nan-

nizzi, in Pollacci, Tratt. Micopat. Umana, *4*, 1934, 42; *Fusiformis ramosus* Topley and Wilson, Princ. Bact. and Immun., 2nd ed., 1936, 358; Hauduroy et al., Dict. d. Bact. Path., 1937, 71 regard *Bacillus poeciloides* (*Eubacterium poeciloides*) as a synonym; Prévot, Ann. Inst. Past., *60*, 1938, 296.) Commonly found in appendicitis.

2. *Ramibacterium ramosoides* (Rüneberg) Prévot. (*Bacillus ramosoides* Rüneberg, Arb. a. d. path. Inst. d. Univ. Helsingfors, *2*, 1908, 271, see Cent. f. Bakt., I Abt., Ref., *43*, 1909, 665; Prévot, Ann. Inst. Past., *60*, 1938, 296.) From peritoneal fluid in appendicitis.

3. *Ramibacterium pseudoramosum* (Distaso) Prévot. (*Bacillus pseudoramosus* Distaso, Cent. f. Bakt., I Abt., Orig., *62*, 1912, 441; *Bacteroides pseudoramosus* Bergey et al., Manual, 1st ed., 1923, 259; Prévot, Ann. Inst. Past., *60*, 1938, 296.) From human feces.

Genus IV. **Cillobacterium** *Prévot.*
(Ann. Inst. Past., *60*, 1938, 294.)

Motile, straight or curved rods. Peritrichous. Not capsulated. Gram-positive. Anaerobic.

1. *Cillobacterium moniliforme* (Repaci) Prévot. (*Bacillus moniliformis* Repaci, Compt. rend. Soc. Biol., Paris, *61*, 1910, 216; Prévot, Ann. Inst. Past., *60*, 1938, 296.) From the respiratory system.

2. *Cillobacterium endocarditis* (Routier and Braunberger) Prévot. (Bacille BG, Routier and Braunberger, Compt. rend. Soc. Biol., Paris, *115*, 1934, 611; Prévot, Ann. Inst. Past., *60*, 1938, 296.) From febrile endocarditis.

3. *Cillobacterium meningitis* Prévot. (Stamm S. V., Ghon, Mucha and Müller, Cent. f. Bakt., I Abt., Orig., *41*, 1906, 145 and 693; Prévot, Ann. Inst. Past., *60*, 1938, 297.) From meningitis following chronic otitis.

4. *Cillobacterium spatuliforme* Prévot (see *Bacillus tenuis spatuliformis* Distaso). Said to belong to *Bacillus welchii* group but no spores observed.

5. *Cillobacterium multiforme* Prévot (see *Bacillus multiformis* Distaso). Said to belong to *Bacillus welchii* group but no spores observed.

Genus V. **Bifidobacterium** *Orla-Jensen.*
(Orla-Jensen, Le Lait, *4*, 1924, 469; *Bifidibacterium* (sic) Prévot, Ann. Inst. Past., *60*, 1938, 303.)

Non-motile rods which may be swollen. The ends may be bifurcate or double bifurcate. Gram-positive. Anaerobic. This genus is regarded as one of four genera of lactic acid, rod-shaped bacteria by Orla-Jensen, and he states that the organisms in the genus form dextro rotatory lactic acid. It is placed in the Order *Actinomycetales* by Prévot.

1. *Bifidibacterium bifidum* (Tissier) Prévot. (Prévot, Ann. Inst. Past., *60*, 1938, 303.) See *Lactobacillus bifidus* (Tissier) Holland.

2. *Bifidibacterium appendicitis* Prévot. (Bacillus α Lotti, Ann. Ig. Sper., *19*, 1909, 75; Prévot, Ann. Inst. Past., *60*, 1938, 303.) From an infected appendix.

3. *Bifidibacterium constellatum* (White) Prévot. (*Bacillus constellatus* White, Jour. Path. and Bact., *24*, 1921, 69; Prévot, Ann. Inst. Past., *60*, 1938, 303.) From the intestine of bees.

4. *Bifidibacterium intestinalis* Prévot. (*Bacillus intestinalis tuberculiformis* Jacobsen. Also uses *Bacillus tuberculiformis* and *Bacillus tuberculiformis intestinalis*, Ann. Inst. Past., *22*, 1908, 315; Prévot, Ann. Inst. Past., *60*, 1938, 303.) From feces of an infant.

5. *Bifidibacterium cornutum* (Distaso) Prévot. (*Bacillus cornutus* Distaso, Cent. f. Bakt., I Abt., Orig., *62*, 1912, 443; *Bacteroides cornutus* Castellani and Chalmers, Man. Trop. Med., 1919, 960; Prévot, Ann. Inst. Past., *60*, 1938, 303.) From human mouth and intestine.

6. *Bifidibacterium bifurcatum* Prévot. (*Bacillus bifurcatus gazogenes* Choukévitch, Ann. Inst. Past., *22*, 1911, 348; Prévot, Ann. Inst. Past., *60*, 1938, 303.) From intestine of a horse.

Genus II. Microbacterium *Orla-Jensen.**

(The Lactic Acid Bacteria, 1919, 179.) From Greek *mikros*, small and M. L. *bacterium*, a small rod.

Small rods. Non-motile. Gram-positive. Produce lactic acid but no gas from carbohydrates. Surface growth on media is good. Produce catalase. Usually heat-resistant. Found in dairy products and utensils, fecal matter and soil.

The type species is *Microbacterium lacticum* Orla-Jensen.

Key to the species of genus Microbacterium.

I. Acid from starch; survives 85°C for 2½ minutes.
  1. *Microbacterium lacticum.*

II. No acid from starch; survives 71.6°C for 2½ minutes.
  2. *Microbacterium flavum.*

1. **Microbacterium lacticum** Orla-Jensen. (The Lactic Acid Bacteria, 1919, 179; *Corynebacterium lacticum* Jensen, Proc. Linnean Soc. of New So. Wales, *59*, 1934, 50.) From Latin *lac*, milk; M. L., pertaining to milk.

Small thin rods: 0.3 by 1.0 micron; may have coccus-like appearance. Non-motile. Granular. Gram-positive. Angular and pallisade arrangements of cells are characteristic.

Agar slant: White or at times slight greenish-yellow growth; adherent.

Gelatin: No liquefaction.

Milk: Acid, coagulation variable.

Nitrites usually not produced from nitrates.

Indole not formed.

Acid from glucose, fructose, mannose, galactose, maltose, lactose, dextrin and starch. No acid from xylose, arabinose, rhamnose, or raffinose. Dextro lactic acid formed.

Catalase is produced.

Temperature relations: Minimum 10°C. Optimum 30°C. Maximum 35°C. Survives 85°C for 2½ minutes in skim-milk.

Aerobic to facultative anaerobic.

Source: From cheese, milking equipment, grass, human and bovine feces. Orla-Jensen (*loc. cit.*, 180–181) identifies the *Bacillus acidophilus* cultures obtained by him from the Král collection as belonging to this species. The characters of the Král cultures deviate from the characters of *Bacillus acidophilus* as given by Moro.

Habitat: Human and bovine intestinal tract and probably soil.

2. **Microbacterium flavum** Orla-Jensen. (Orla-Jensen, The Lactic Acid Bacteria, 1919, 181; *Mycobacterium flavum* Jensen, Proc. Linnean Soc. of New So. Wales, *59*, 1934, 34.) From Latin *flavus*, yellow.

Rods: 0.5 by 1 to 2 microns. Granular and therefore sometimes confused with micrococci. Non-motile. Gram-positive.

Agar: Surface growth usually yellow and viscid.

Gelatin: No liquefaction.

Broth containing 10 per cent salt: Grows as flaky precipitate.

Milk: Slight acidity with no coagulation.

Nitrites produced from nitrates.

Indole not formed.

Acid from glucose, fructose, mannose, galactose, raffinose and mannitol. No acid from xylose, arabinose, rhamnose,

* Arranged by Prof. C. S. Pederson, New York State Experiment Station, Geneva, New York, June, 1938; further revision by Dr. M. L. Speck, Baltimore, Maryland, Sept., 1943.

sorbitol, inulin, starch, or salicin. Dextro lactic acid formed.

Catalase is produced.

Temperature relations: Optimum 30°C. Maximum 35°C. Minimum 20°C. Survives 71.6°C for 2½ but not 10 minutes.

Aerobic to facultative anaerobic.

Source: From milk, cheese, butter, milking equipment, bovine feces.

Habitat: Bovine intestinal tract and probably soil.

Appendix: While Orla-Jensen has placed the following species in the genus *Microbacterium*, the description is incomplete and the organism differs from the other species in the genus in several important characters. Therefore it is placed in this appendix.

Microbacterium liquefaciens Orla-Jensen. (Orla-Jensen, The Lactic Acid Bacteria, 1919, 182; *Corynebacterium liquefaciens* Jensen, Proc. Linnean Soc. of New So. Wales, *59*, 1934, 49.) From Latin *liqueo*, to be liquid; *facio*, to make.

Morphologically resembles *Microbacterium lacticum*.

Agar: Surface growth is faint yellowish-green.

Gelatin: Liquefied.

Milk: Rennet coagulation in 1 to 3 weeks; the casein is peptonized gradually.

Catalase is produced.

Temperature relations: Optimum 30°C. Withstands heating to 80°C.

Action on carbohydrates has not been described; Orla-Jensen states that very little acid is produced.

Source: From milk and more frequently from cheese.

Habitat: Presumably dairy products.

NOTE. The following species may belong here: *Bacterium caseolyticum* Kitahara, Jour. Agr. Chem. Soc. Japan, Tokyo, *14*, 1938, 121 and 1461. A Gram-positive, acid-forming and proteolytic rod said by the author to be related to *Microbacterium liquefaciens*.

Genus III. **Propionibacterium** *Orla-Jensen.**

(Cent. f. Bakt., II Abt., *22*, 1909, 337.) From M. L., propionic, and *bacterium*, a small rod or stick.

Non-motile. Non-spore-forming. Gram-positive bacteria growing under anaerobic conditions in neutral media as short diphtheroid rods, sometimes resembling streptococci; under aerobic conditions with heavy inoculum growing as long, irregular, club-shaped and branched cells. Metachromatic granules demonstrable with Albert's stain. Ferment lactic acid, carbohydrates, and polyalcohols with the formation of propionic and acetic acids and carbon dioxide. As a rule strongly catalase positive, sometimes weakly so. Strong tendency towards anaerobiosis; development very slow, macroscopically visible colonies generally not discernible in less than 5 to 7 days.† Nutritional requirements complex. Development best in yeast extract media with addition of lactates or simple carbohydrates. Optimum temperature 30°C. Found in dairy products, especially hard cheeses.

The type species is *Propionibacterium freudenreichii* van Niel.

Key to the species of genus **Propionibacterium.**

I. In yeast extract-glucose media growth occurs in the form of small streptococci. Dirty cream-colored growth in stabs, with slight surface growth of same color. Sucrose and maltose not fermented.
  A. Not fermenting lactose.
    1. *Propionibacterium freudenreichii.*
  B. Fermenting lactose.
    2. *Propionibacterium shermanii.*

II. In yeast extract-glucose media growth occurs in the form of typical short rods of diphtheroid appearance. Distinct surface growth in stabs. Sucrose and maltose are fermented.
  A. Growth brownish-red.
    1. Ferments raffinose and mannitol, but not sorbitol.
      3. *Propionibacterium rubrum.*
    2. Ferments sorbitol, but not raffinose and mannitol.
      4. *Propionibacterium thoenii.*
  B. Growth in stab cream-colored.
    1. Surface growth cream-colored.
      a. Ferments l-arabinose and rhamnose.
        5. *Propionibacterium zeae.*
    2. Surface growth yellow to orange.
      a. Growth in liquid media flocculent, as if agglutinated.
        6. *Propionibacterium peterssonii.*
      aa. Growth in liquid media dispersed, smooth.

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* Revised by Prof. C. B. van Niel, Hopkins Marine Station, Pacific Grove, California, June, 1938; further revision by Prof. Van Niel, January, 1944.

† In an atmosphere containing 5 per cent carbon dioxide, growth is enhanced both aerobically and anaerobically. Contrary to the claim made by Krebs and Eggleston (Biochem. Jour., *35*, 1941, 676) a differential effect of carbon dioxide tension on aerobic and anaerobic development has never been observed.

b. Do not ferment dextrin, glycogen or starch.

7. *Propionibacterium jensenii.*

8. *Propionibacterium raffinosaceum.*

bb. Ferments dextrin, glycogen and starch.

9. *Propionibacterium technicum.*

III. In yeast extract-glucose media growth occurs in the form of highly irregular cells, giving the appearance of involution forms. Distinct surface growth in stabs. Both d- and l- arabinose are fermented.

A. Involution forms large, swollen spheres. Surface growth orange-yellow. Does not ferment xylose and rhamnose.

10. *Propionibacterium arabinosum.*

B. Involution forms long, irregular rods. Surface growth cream-colored. Ferments xylose and rhamnose.

11. *Propionibacterium pentosaceum.*

1. **Propionibacterium freudenreichii** van Niel. (*Bacterium acidi propionici a*, von Freudenreich and Orla-Jensen, Cent. f. Bakt., II Abt., *17*, 1906, 532; *Bacterium acidi propionici* var. *fuscum* Thöni and Allemann, Cent. f. Bakt., II Abt., *25*, 1910, 29; van Niel, The Propionic Acid Bacteria, Haarlem, 1928, 162; Werkman and Brown, Jour. Bact., *26*, 1933, 397.) Named for Eduoard von Freudenreich, the Swiss bacteriologist, who isolated this species.

Description taken from van Niel, and Werkman and Brown.

Small spherical cells, 0.5 to 0.6 micron, mostly in pairs and short chains. Little difference in morphology between growth from anaerobic solid media and neutral or acid liquid media. Aerobic growth irregular, club-shaped and branched, long rods. Non-motile. Show metachromatic granules. Gram-positive.

Yeast gelatin-lactate stab: No liquefaction.

Yeast agar-lactate stab: Dirty grayish-creamy development in stab; very slight surface growth of same color.

Liquid media: Distinctly turbid with grayish-creamy, ropy sediment.

Litmus milk: Slight development, faint reduction. Not coagulated.

Catalase positive.

Indole not formed.

Nitrites not produced from nitrates.

Ferments lactic and pyruvic acids, glycerol, dihydroxyacetone, glucose, fructose, mannose and galactose with the formation chiefly of propionic and acetic acids, and carbon dioxide.

Acid from erythritol, adonitol, inositol and esculin. No acid from amygdalin, d- and l-arabinose, dextrin, dulcitol, glycogen, inulin, lactose, maltose, mannitol, melezitose, melibiose, perseitol, raffinose, rhamnose, sucrose or xylose.

Anaerobic.

Distinctive characters: Inability to ferment any of the disaccharides when inoculated in yeast extract-sugar media.

Source: From dairy products; raw market milk, Swiss cheese.

Habitat: Dairy products.

2. **Propionibacterium shermanii** van Niel. (*Bacterium acidi propionici d*, Sherman, Jour. Bact., *6*, 1921, 387; van Niel, The Propionic Acid Bacteria, Haarlem, 1928, 163; Werkman and Brown, Jour. Bact., *26*, 1933, 400.) Named for J. M. Sherman, the American bacteriologist, who isolated this species.

Description taken from van Niel, and Werkman and Brown.

Small spherical cells, 0.5 to 0.6 micron, mostly in pairs and short chains. Little difference in morphology between growth from anaerobic solid media and neutral or acid liquid media. Aerobic growth irregular, club-shaped and branched rods. Non-motile. Show metachromatic granules. Gram-positive.

Yeast gelatin-lactate stab: No liquefaction.

Yeast agar-lactate stab: Dirty grayish-creamy development in stab; very slight surface growth of same color.

Liquid media: Distinctly turbid with grayish-creamy, ropy sediment.

Litmus milk: Acid coagulation.

Catalase positive.

Indole not formed.

Nitrites not produced from nitrates.

Ferments lactic and pyruvic acids, glycerol, dihydroxyacetone, glucose, fructose, mannose, galactose and lactose with the formation chiefly of propionic and acetic acids, and carbon dioxide. Occasionally arabinose is fermented.

Acid from erythritol, adonitol, arabitol, inositol and esculin. No acid from amygdalin, dextrin, dulcitol, glycogen, inulin, maltose, mannitol, melezitose, melibiose, perseitol, raffinose, rhamnose, salicin, sorbitol, sucrose, starch, trehalose or xylose.

Anaerobic.

Distinctive characters: Resembles *Propionibacterium freudenreichii* in every respect, but differs in its ability to ferment lactose.

Source: From dairy products; Swiss cheese and buttermilk.

Habitat: Dairy products.

3. **Propionibacterium rubrum** van Niel. (*Bacterium acidi propionici* var. *rubrum* Thöni and Allemann (in part), Cent. f. Bakt., II Abt., *25*, 1910, 8; van Niel, The Propionic Acid Bacteria, 1928, 164; Werkman and Brown, Jour. Bact., *26*, 1933, 414.) From Latin *ruber*, red.

Medium-sized, stoutish rods to elongated diplococci, 0.8 by 1.2 microns, occurring singly or in pairs, resembling diphtheroids rather than streptococci. Somewhat more slender in media without fermentable carbohydrate. Aerobic growth irregular, club-shaped and branched rods. Non-motile. Show metachromatic granules. Gram-positive.

Yeast gelatin-lactate stab: No liquefaction.

Yeast agar-lactate stab: Brownish-red development in stab, with appreciable dome-shaped surface growth of same color. (Also see Margolena and Hansen, Cent. f. Bakt., II Abt., *99*, 1938, 107.)

Liquid media: Turbidity in early stages, sediment red and smooth.

Litmus milk: Acid coagulation.

Catalase positive; very weak for aerobically grown cells.

Indole not formed.

Nitrites not produced from nitrates.

Ferments lactic and pyruvic acids, glycerol, dihydroxyacetone, glucose, fructose, mannose, galactose, sucrose, maltose, lactose, raffinose and mannitol with the production chiefly of propionic and acetic acids and carbon dioxide.

Acid from erythritol, adonitol, arabitol, amygdalin, esculin, salicin, melezitose and trehalose. No acid from d- and l-arabinose, dextrin, dulcitol, glycogen, inulin, melibiose, perseitol, rhamnose, sorbitol, starch or xylose.

Less anaerobic than *Propionibacterium freudenreichii* and *Propionibacterium shermanii*.

Distinctive characters: Production of brownish-red pigment under anaerobic and aerobic conditions. Fermentation of raffinose and mannitol, not of sorbitol.

Source: From various dairy products.

Habitat: Dairy products.

4. **Propionibacterium thoenii** van Niel. (*Bacterium acidi propionici* var. *rubrum* Thöni and Allemann (in part), Cent. f. Bakt., II Abt., *25*, 1910, 8; van Niel, The Propionic Acid Bacteria, 1928, 164; Werkman and Brown, Jour. Bact., *26*, 1933, 412.) Named for Thöni, the Swedish bacteriologist, who isolated this organism.

Description taken from van Niel, and Werkman and Brown.

Medium sized, stoutish rods to elongated diplococci, 1.0 by 1.5 microns, occurring singly or in pairs, resembling

diphtheroids. In media without fermentable carbohydrate, small streptococci. Aerobic growth irregular, club-shaped and branched rods. Non-motile. Shows metachromatic granules. Gram-positive.

Yeast gelatin-lactate-stab: No liquefaction.

Yeast agar-lactate-stab: Brownish-red growth throughout stab, with appreciable dome-shaped surface growth of same color.

Liquid media: Turbidity in early stages, sediment smooth and red.

Litmus milk: Mostly acid coagulation.

Catalase positive.

Indole not formed.

Nitrites not produced from nitrates.

Ferments lactic and pyruvic acids, glycerol, dihydroxyacetone, glucose, fructose, mannose, galactose, sucrose, maltose, lactose and sorbitol with the formation of propionic and acetic acids, and carbon dioxide.

Acid from adonitol, arabitol, erythritol, esculin, salicin and trehalose. No acid from amygdalin, arabinose, dextrin, dulcitol, glycogen, inulin, mannitol, melezitose, melibiose, perseitol, pectin, raffinose, rhamnose, starch or xylose.

Domke (Milchwirtsch. Forsch., *15*, 1933, 480) reports that this species may or may not ferment lactose and may or may not produce acid from esculin and salicin.

Less anaerobic than *Propionibacterium freudenreichii* and *Propionibacterium shermanii*.

Distinctive characters: Closely resembles *Propionibacterium rubrum* in morphology and in the production of brownish-red pigment under aerobic and anaerobic conditions. Differs from this species in its inability to ferment raffinose and mannitol, whereas fermentation of sorbitol occurs.

The biochemical characteristics of a ten-year-old stock culture have remained unchanged.

Source: From cheese and buttermilk.

Habitat: Dairy products.

5. **Propionibacterium zeae** Hitchner. (Hitchner, Jour. Bact., *23*, 1932, 40; *28*, 1935, 473; Werkman and Brown, Jour. Bact., *26*, 1933, 411.) From Greek *zea*, spelt, a kind of grain; M. L. *Zea*, a generic name.

Description of culture isolated by Hitchner.

Cells in neutral lactate media spherical, 0.8 micron, usually occurring as short streptococci. In carbohydrate media which turn acid during development, distinctly rod-shaped, 0.8 by 2.0 to 3.0 microns, with a slight tendency to the formation of club-shaped cells. Appearance typically diphtheroid. Aerobic growth irregular, club-shaped and branched rods. Non-motile. Show metachromatic granules. Gram-positive.

Yeast gelatin-lactate-stab: No liquefaction.

Yeast agar-lactate-stab: Cream-colored growth in stab, with distinct surface growth of same color.

Liquid media: Distinctly turbid; cream-colored; smooth sediment, very ropy.

Litmus milk: Coagulated, acid.

Catalase positive, especially when grown in neutral media.

Indole not formed.

Nitrites not produced from nitrates.

Ferments lactic and pyruvic acids, glycerol, dihydroxyacetone, l-arabinose, rhamnose, glucose, fructose, mannose, galactose, sucrose, cellobiose, maltose, lactose and mannitol with the formation of propionic and acetic acids and carbon dioxide.

Acid from salicin. No acid from d-arabinose, dextrin, dulcitol, glycogen, inulin, starch or xylose.

Less anaerobic than *Propionibacterium freudenreichii* and *Propionibacterium shermanii*.

Distinctive characters: Cream-colored surface growth, ability to ferment l-arabinose and rhamnose, but not d-arabinose and xylose.

Source: Not definitely recorded,

Probably from silage.

Habitat: Dairy products.

6. **Propionibacterium peterssonii** van Niel. (*Bacterium acidi propionici c*, Troili-Petersson, Cent. f. Bakt., II Abt., *24*, 1909, 333; van Niel, The Propionic Acid Bacteria, 1928, 163; Werkman and Brown, Jour. Bact., *26*, 1933, 406.) Named for Gerda Troili-Petersson, the Swedish bacteriologist, who isolated this organism.

Description taken from van Niel, and Werkman and Brown.

Cells in neutral media spherical, 0.8 micron, occurring as short streptococci in clumps. In carbohydrate media which turn acid during development, rod-shaped cells in clumps, 0.8 by 1.5 to 2.0 microns. Aerobic growth, heavily swollen and branched rods. Non-motile. Show metachromatic granules. Gram-positive.

Yeast gelatin-lactate stab: No liquefaction.

Yeast agar-lactate stab: Cream-colored growth, dry and wrinkled, resembling that of *Mycobacterium spp.*

Liquid media: No turbidity, sediment a coherent layer, cream-colored.

Litmus milk: Acid, coagulated.

Catalase positive; aerobically developed growth very slightly so.

Indole not formed.

Nitrites not produced from nitrates.

Ferments lactic and pyruvic acids, glycerol, dihydroxyacetone, glucose, fructose, mannose, galactose, sucrose, maltose and lactose with the formation of propionic and acetic acids, and carbon dioxide.

Acid from esculin and salicin. No acid from d- and l-arabinose, cellobiose, dextrin, dulcitol, glycogen, inulin, perseitol, pectin, raffinose, rhamnose, sorbitol, starch or xylose.

Less anaerobic than *Propionibacterium freudenreichii* and *Propionibacterium shermanii.*

Distinctive character: Growth in liquid media in clumps, giving the cultures the appearance of agglutinated bacteria. So far, the only species among the propionic acid bacteria possessing this characteristic.

Source: From cheese and soil.

Habitat: Dairy products.

7. **Propionibacterium jensenii** van Niel. (*Bacterium acidi propionici b*, von Freudenreich and Orla-Jensen, Cent. f. Bakt., II Abt., *17*, 1906, 532; van Niel, The Propionic Acid Bacteria, 1928, 163; Werkman and Brown, Jour. Bact., *26*, 1933, 404.) Named for Prof. S. Orla-Jensen, the Danish bacteriologist, who isolated this organism.

Description taken from van Niel, and Werkman and Brown.

In neutral media spherical to short rod-shaped cells, often in pairs or short chains, 0.8 by 0.8 to 1.5 microns, of typical diphtheroid appearance. Morphology little influenced by developing acidity. Aerobic growth, irregular long rods, swollen and branched. Non-motile. Metachromatic granules. Gram-positive.

Yeast gelatin-lactate stab: No liquefaction.

Yeast agar-lactate stab: Cream-colored growth in stab, orange-yellow, dome-shaped surface growth.

Liquid media: Turbid in early stages; cream-colored, smooth sediment.

Litmus milk: Coagulated, acid.

Catalase: Strongly positive.

Indole not formed.

Nitrites not produced from nitrates.

Ferments lactic and pyruvic acids, glycerol, dihydroxyacetone, glucose, fructose, mannose, galactose, sucrose, maltose, lactose and sometimes raffinose and mannitol with the formation of propionic and acetic acids, and carbon dioxide.

Acid from adonitol, arabitol, erythritol, esculin, inositol and trehalose. No acid from arabinose, cellobiose, dextrin, dulcitol, glycogen, inulin, perseitol, pectin, rhamnose, salicin, sorbitol, starch or xylose.

Less anaerobic than *Propionibacterium freudenreichii*.

Distinctive characters: Morphologically similar to *Propionibacterium rubrum* and *Propionibacterium thoenii* from which it is chiefly distinguished by the failure to produce a red pigment under anaerobic conditions. The yellow surface growth distinguishes *Propionibacterium jensenii* from *Propionibacterium zeae*, as also the inability of the former to ferment l-arabinose and rhamnose.

Source: From cheese and butter.

Habitat: Dairy products.

8. **Propionibacterium raffinosaceum** Werkman and Kendall. (*Propionibacterium jensenii* var. *raffinosaceum* van Niel, The Propionic Acid Bacteria, 1928, 162; Werkman and Kendall, Iowa State Coll. Jour. Sci., *6*, 1931, 17; Werkman and Brown, Jour. Bact., *26*, 1933, 402.) From M. L. *raffinosum*, the sugar raffinose.

Description taken from van Niel, and Werkman and Brown.

Cells in neutral media spherical to short rod-shaped cells, 0.8 by 0.8 to 1.5 microns, of typical diphtheroid appearance. In media in which acid is produced the cells are somewhat longer rod-shaped, to 2 microns in length. Aerobic growth irregular, long rods, swollen and branched. Non-motile. Metachromatic granules. Gram-positive.

Yeast gelatin-lactate-stab: No liquefaction.

Yeast agar-lactate-stab: Cream-colored growth in stab; distinct, orange-yellow surface growth.

Liquid media: Turbid in early stages, cream-colored, smooth sediment.

Litmus milk: Coagulated, acid.

Catalase positive; aerobically grown only very slightly so.

Indole not formed.

Nitrites not produced from nitrates.

Ferments lactic and pyruvic acids, glycerol, dihydroxyacetone, glucose, fructose, mannose, galactose, cellobiose, maltose, lactose, sucrose, raffinose and mannitol with the production of propionic and acetic acids, and carbon dioxide.

Acid from adonitol, amygdalin, arabitol, erythritol, esculin, inositol, melezitose, salicin and trehalose. No acid from d- and l-arabinose, dextrin, dulcitol, glycogen, inulin, melibiose, perseitol, pectin, rhamnose, sorbitol, starch or xylose.

Less anaerobic than *Propionibacterium freudenreichii*.

Distinctive characters: Differs from *Propionibacterium jensenii* in its somewhat greater length and the ability to ferment cellobiose and salicin; the behaviour of *Propionibacterium jensenii* towards raffinose and mannitol is not constant, and hence cannot be used as a differential character. Werkman and Kendall have reported different agglutination reactions for *Propionibacterium jensenii* and *Propionibacterium raffinosaceum*.

Source: From buttermilk.

Habitat: Dairy products.

9. **Propionibacterium technicum** van Niel. (Van Niel, The Propionic Acid Bacteria, 1928, 164; Werkman and Brown, Jour. Bact., *26*, 1933, 401.) From Greek *technicus*, technical; M. L., of industrial significance.

Description taken from van Niel.

In neutral media spherical cells, 0.8 micron, in pairs and short chains. In acid media short rods, 0.6 by 1.0 to 1.5 microns, often in pairs, with typical diphtheroid appearance. Aerobic growth in the form of irregular long rods, swollen and branched. Non-motile. Metachromatic granules. Gram-positive.

Yeast gelatin-lactate-stab: No liquefaction.

Yeast agar-lactate-stab: Cream-colored development in stab, with distinct yellow surface growth.

Liquid media: Turbid in early stages, cream-colored, somewhat flocculent sediment.

Litmus milk: Coagulation, acid.

Catalase positive.

Indole not formed.

Nitrites not produced from nitrates.

Ferments lactic and pyruvic acids, glycerol, dihydroxyacetone, arabinose, glucose, galactose, fructose, mannose, lactose, maltose, sucrose, raffinose, dextrin, glycogen and starch with the formation of propionic and acetic acids, and carbon dioxide.

Acid from esculin, salicin and mannitol. No acid from dulcitol, inulin or xylose.

Anaerobic, but less so than *Propionibacterium freudenreichii*.

Distinctive characters: The ability to ferment the polysaccharides dextrin, glycogen and starch.

Source: From Edam and Tilsit cheese.

Habitat: Dairy products.

10. **Propionibacterium arabinosum** Hitchner. (Hitchner, Jour. Bact., *23*, 1932, 40; *28*, 1934, 473; Werkman and Brown, Jour. Bact., *26*, 1933, 410.) From M. L. *arabicum*, gum Arabic; M. L. *arabinosum*, arabinose.

Description of culture isolated by Hitchner.

Cells in neutral lactate media spherical, 0.8 micron, in pairs and short chains. In acid media swollen spheres and ellipsoidal cells occur, mostly 2.0 by 3.0 to 3.5 microns, often in pairs and short chains. Non-motile. Metachromatic granules. Gram-positive.

Yeast gelatin-lactate-stab: No liquefaction.

Yeast agar-lactate-stab: Cream-colored growth in stab, with distinct orange-yellow surface growth.

Liquid cultures: Turbid in early stages, cream-colored, smooth sediment.

Litmus milk: No coagulation.

Catalase very slightly positive.

Indole not formed.

Nitrite production not recorded.

Ferments lactic and pyruvic acids, glycerol, dihydroxyacetone, d- and l-arabinose, glucose, galactose, fructose, mannose, cellobiose, maltose, sucrose, raffinose and mannitol with the production of propionic and acetic acids, and carbon dioxide.

Acid from sorbitol. No acid from dulcitol, xylose, rhamnose, salicin or inulin.

Anaerobic, but less so than *Propionibacterium freudenreichii*.

Distinctive characters: The development of spherical involution forms in acid media, the almost complete absence of catalase, the ability to ferment both d- and l-arabinose, but not xylose and rhamnose.

Source: Not definitely stated.

Habitat: Dairy products.

NOTE: The strain obtained from Dr. E. B. Fred produced only minute amounts of acid from lactose and starch. It is questionable whether these carbohydrates are fermented.

11. **Propionibacterium pentosaceum** van Neil. (*Bacillus acidi propionici* von Freudenreich and Orla-Jensen, Cent. f. Bakt., II Abt., *17*, 1906, 532; van Niel, The Propionic Acid Bacteria, 1928, 163; Werkman and Brown, Jour. Bact., *26*, 1933, 408.) From M. L. *pentosum*, a pentose.

Description taken from van Niel, and Werkman and Brown.

In neutral lactate media cells spherical, 0.8 micron, in pairs and short chains. In media developing acidity long, irregular rods, swollen and branched, to 3 to 4 microns in length. Aerobic growth irregular, swollen and branched, long rods. Non-motile. Metachromatic granules. Gram positive.

Yeast gelatin-lactate stab: No liquefaction.

Yeast agar-lactate stab: Cream-colored development in stab, with abundant, cream-colored surface growth.

Liquid media: Turbid in early stages; smooth, creamy sediment, ropy.

Litmus milk: Coagulated, acid.

Catalase: Slightly positive.

Indole not formed.

Nitrites and free nitrogen produced from nitrates.

Ferments lactic and pyruvic acids, glycerol, dihydroxyacetone, d- and l-arabinose, xylose, rhamnose, glucose, galactose, fructose, mannose, cellobiose, lactose, maltose, sucrose, raffinose, mannitol and sorbitol with the formation of propionic and acetic acids, and carbon dioxide.

Acid from adonitol, arabitol, erythritol, esculin, inositol, salicin and trehalose. No acid from dextrin, dulcitol, glycogen, inulin, perseitol or pectin.

Anaerobic, but less so than any of the other species of the genus.

Distinctive characters: The formation of long, rod-shaped involution forms in acid media; the absence of pigment production, and the ability to ferment d- and l-arabinose, rhamnose and xylose.

Source: From Emmental cheese.

Habitat: Dairy products.

Appendix: Cultures of the following species have not been available for study. It is probable that these duplicate previously described species.

Propionibacterium amyloaceum var. *auranticum* Sakaguchi, Swasaki and Yamada. (Bull. Agric. Chem. Soc. Japan, *17*, 1941, 13.) From cheese. Resembles *Propionibacterium pentosaceum* closely.

Propionibacterium coloratum Sakaguchi et al. (*loc. cit.*). From cheese. Resembles *Propionibacterium thoenii.*

Propionibacterium globosum Sakaguchi et al. (*loc. cit.*). From cheese. Resembles *Propionibacterium shermanii.* Said not to ferment glycerol and erythritol.

Propionibacterium japonicum Sakaguchi et al. (*loc. cit.*). From cheese. Said not to ferment glycerol and erythritol.

Propionibacterium orientum Sakaguchi et al. (*loc. cit.*). From cheese. Ferments l-arabinose. Resembles *Propionibacterium shermanii.*

Janoschek (Cent. f. Bakt., II Abt., *106*, 1944, 321) has suggested a key for the identification of the species in this genus. This is based on chromogenesis and cultural characters. He recognizes three additional species: *Propionibacterium casei, Propionibacterium pituitosum* and *Propionibacterium sanguineum.*

Genus IV. Butyribacterium *Barker and Haas.**

(Jour. Bact., *47*, 1944, 301.) From the chemical term, butyric and M. L. *bacterium*, a small rod.

Non-motile, anaerobic to microaerophilic, straight or slightly bent rods. Gram-positive. Ferment carbohydrates and lactic acid forming acetic and butyric acids, and carbon dioxide. Generally catalase negative but sometimes weakly positive. Intestinal parasites.

The type species is *Butyribacterium rettgeri* Barker and Haas.

1. **Butyribacterium rettgeri** Barker and Haas. (Strain 32, Lewis and Rettger, Jour. Bact., *40*, 1940, 298; Barker and Haas, Jour. Bact., *47*, 1944, 303.) Named for L. F. Rettger, The American bacteriologist.

Rods: Straight or slightly bent, non-capsulated. 0.7 by 2.3 microns. Occur singly, in pairs and short chains. No branched cells observed but some cells have swollen club-shaped ends. Non-motile. Gram-positive.

Glucose-cysteine agar: Colonies circular, entire or finely irregular margin, translucent, often with opaque center, grayish-white with yellowish tinge, convex when small, later umbonate, glistening, smooth, finely granular. Develop slowly attaining a diameter of 1.5 mm in 7 days.

Tryptone-yeast extract-lactate agar: Colonies similar to above except larger (2 mm in 4 days at 37°C). Pulvinate rather than umbonate in cross sections.

Glucose-cysteine-broth: Abundant turbidity and sediment. No pellicle.

Agar stab (King and Rettger's medium, Jour. Bact., *44*, 1942, 302): Heavy growth in 2 days. Gas production often causes slight splitting of agar.

Acetic and butyric acid and CO_2 produced from glucose and maltose. Occasionally a small amount of visible gas is produced. Lactic acid fermented readily without visible gas. Arabinose, xylose, lactose, sucrose, trehalose, rhamnose, mannitol, sorbitol, dulcitol and glycerol are not fermented.

Not proteolytic.

Indole and hydrogen sulfide not formed.

Temperature relations: Optimum 37°C. Maximum 40 to 45°C. Minimum 15°C.

Generally catalase negative.

Anaerobic.

Source: From intestinal contents of a white rat.

Habitat: Presumably found generally in the intestine of mammals.

NOTES: Pederson (Jour. Bact., *50*, 1945, 478) has found that cultures of two species described by Eggerth (Jour. Bact., *30*, 1935, 289 and 290) produce higher fatty (presumably butyric) acids and lactic acid from glucose. These are named *Bacteroides avidus* and *B. limosus* by Eggerth. Probably these species belong in the genus *Butyribacterium*.

Bacillus cadaveris butyricus Buday (Cent. f. Bakt., I Abt., *24*, 1898, 374) may also belong in this genus.

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* Prepared by Prof. C. S. Pederson, New York State Experiment Station, Geneva, New York, January, 1945; reviewed by Dr. H. A. Barker, Berkeley, California.

FAMILY VIII. CORYNEBACTERIACEAE LEHMANN AND NEUMANN.

(Bakt. Diag., 4 Aufl., *2*, 1907, 500.)

Non-motile (motile in *Listeria*) rods, frequently banded or beaded with metachromatic granules. May show marked diversity of form. Branching cells have been observed in a few species but these are uncommon. Generally Gram-positive but this reaction may vary depending on the nature of the cells. Where pigment is formed, it is grayish-yellow to orange or pink in color. Aerobic to microaerophilic. Anaerobic species have been reported. Gelatin may be liquefied and nitrites may be produced from nitrates. Animal and plant parasites and pathogens. Also from dairy products, soil and water.

Key to the genera of family **Corynebacteriaceae**.

I. Aerobic to microaerophilic, non-motile (or questionably motile) rods which are variable in form. Animal and plant parasites and pathogens, with some from dairy products, soil and water.

Genus I. *Corynebacterium*, p. 381.

II. Small aerobic rods with 1 to 4 flagella. Causes a monocytosis in warm-blooded animals.

Genus II. *Listeria*, p. 408.

III. Microaerophilic, non-motile rods to long filaments. Pathogenic on warm-blooded animals.

Genus III. *Erysipelothrix*, p. 410.

Genus I. **Corynebacterium** *Lehmann and Neumann.**

(Lehmann and Neumann, Bakt. Diag., 1 Aufl., *2*, 1896, 390; *Corynethrix* Czaplewski, Deutsche med. Wchnschr., *26*, 1900, 723; *Corynemonas* Orla-Jensen, Cent. f. Bakt., II Abt., *22*, 1909, 344; *Corynobacterium* Enderlein, Sitzber. Gesell. Naturf. Freunde, Berlin, 1917, 309; *Plocamobacterium* Löwi, Wiener klin. Wchnschr., *33*, 1920, 730. From Greek *koryne*, club and M. L. *bacterium*, a small rod.

Slender, straight to slightly curved rods, with irregularly stained segments or granules. Frequently show pointed or club-shaped swellings at the ends. Snapping division produces angular and palisade (picket fence) arrangements of cells. Non-motile with possible exceptions as stated in the text. Gram-positive to variable, sometimes young cells and sometimes old cells being Gram-negative. Granules invariably Gram-positive. Generally quite aerobic, but microaerophilic or even anaerobic species occur. Catalase positive. They may or may not liquefy gelatin, and may or may not produce nitrites from nitrates. They may or may not ferment sugars, but they seldom produce a high acidity. Many species oxidize glucose completely to CO_2 and H_2O without producing visible gas. Some pathogenic species produce a powerful exotoxin. This group is widely distributed in nature. The best known species are parasites and pathogens on man and domestic animals. Other species have been found in birds and insects and the group is probably more widely distributed in the animal kingdom than this. Several species are well known plant pathogens while still other common species are found in dairy products, water and soil.

The type species is *Corynebacterium diphtheriae* (Flügge) Lehmann and Neumann.

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* Rearranged by Prof. E. G. D. Murray, McGill University, Montreal, P. Q., Canada and Prof. Robert S. Breed, New York State Experiment Station, Geneva, New York, March, 1938; completely revised by Prof. E. G. D. Murray, Montreal, Prof. Robert S. Breed, Geneva and Prof. Walter H. Burkholder, New York State College of Agriculture, Ithaca, New York, February, 1945.

Key to the species of genus **Corynebacterium.**

I. From human sources.* Non-motile.†
  A. Aerobic. No liquefaction of gelatin.
    1. Acid from glucose and usually maltose and galactose. Usually no acid from sucrose. Causes diphtheria.
      1. *Corynebacterium diphtheriae.*
    2. Not as in 1.
      a. No acid from carbohydrates.
        2. *Corynebacterium pseudodiphtheriticum.*
      aa. Acid from glucose and sucrose.
        b. Highly pleomorphic, varying from cocci to rods.
          3. *Corynebacterium enzymicum.*
        bb. Rods with polar staining with club forms, diphtheroid in appearance.
          4. *Corynebacterium xerose.*
        bbb. Rods as above but characteristic salmon pink growth on coagulated blood serum.
          5. *Corynebacterium hoagii.*
  B. Microaerophilic to anaerobic. Growth feeble or none at all on gelatin.
    6. *Corynebacterium acnes.*

II. From domestic and laboratory animals. Non-motile.
  A. Acid from glucose.
    1. Grows poorly if at all on ordinary gelatin and agar. Slow liquefaction of serum gelatin and coagulated blood serum. Causes suppurative processes in cattle, swine, and other animals.
      7. *Corynebacterium pyogenes.*
    2. No liquefaction of gelatin or blood serum. Grows poorly, if at all, on ordinary gelatin and agar.
      a. Cause of pyelonephritis in cattle.
        8. *Corynebacterium renale.*
      aa. Found in caseous nodules resembling those of tuberculosis. Found in sheep, horses and some other animals.
        9. *Corynebacterium pseudotuberculosis.*
      aaa. From caseous nodules in mice.
        10. *Corynebacterium kutscheri.*
      aaaa. Causes a septicemia in mice.
        11. *Corynebacterium murisepticum.*
  B. No acid from carbohydrates. No liquefaction of gelatin.
    1. From milk and bovine udder.
      12. *Corynebacterium bovis.*

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* Habitat relationships are used because comparative studies of the species in the genus are still completely lacking.

† The reports of motile species in this genus present a puzzling problem, particularly as the motile species of plant pathogens placed in the genus are polar flagellate. Some students of the group feel that, if motile species really exist, they should be placed in a separate genus. Others feel that a more careful study of the described polar flagellate species will show that these species really belong elsewhere. Where authors have reported motility, this fact is indicated in the text. It should be noted that similar uncertainties exist in regard to described cases of motility among the streptococci and lactobacilli.

2. From pneumonia in foals.
   13. *Corynebacterium equi.*

III. From insects. Non-motile.
   A. No acid from carbohydrates. Slow liquefaction of gelatin.
      14. *Corynebacterium paurometabolum.*

IV. Plant pathogens. Non-motile.
   A. Nitrites not produced from nitrates.
      1. Colonies cream-colored. Slow liquefaction of gelatin.
         a. Bluish granules in growth. Attacks alfalfa.
            15. *Corynebacterium insidiosum.*
         aa. No bluish granules. Causes ring rot of potatoes.
            16. *Corynebacterium sepedonicum.*
      2. Colonies yellow.
         a. No liquefaction of gelatin. Causes a wilt and canker of tomatoes.
            17. *Corynebacterium michiganense.*
   B. Nitrites produced from nitrates. Slow or no liquefaction of gelatin.
      1. Colonies yellow. Attack members of the grass family.
         18. *Corynebacterium rathayi.*
         19. *Corynebacterium agropyri.*
      2. Colonies orange. Parasitic on sweet peas, etc.
         20. *Corynebacterium fascians.*

V. From soil and water. Liquefaction of gelatin in all cases but sometimes very slow (7 weeks).
   A. Acid from glucose. Non-motile.
      1. Nitrites not produced from nitrates.
         21. *Corynebacterium helvolum.*
      2. Nitrites produced from nitrates.
         a. Cellulose digested.
            22. *Corynebacterium fimi.*
         aa. Cellulose not digested.
            23. *Corynebacterium tumescens.*
   B. No acid from glucose. Some indication of motility in No. 25.
      1. Cells coccoid to short, straight or curved rods.
         24. *Corynebacterium simplex.*
      2. Young cells curved rods in parallel bundles. These may grow out into filaments with branching.
         25. *Corynebacterium filamentosum.*

1. **Corynebacterium diphtheriae** (Flügge) Lehmann and Neumann. (*Microsporon diphthericum* Klebs (prototype), Verhandl. d. Congr. f. innere Med., *2*, 1883, 143; die Klebs'schen Stäbchen, Löffler, Mitteil. a. d. kaiserl. Gesundheitsamte, 1884; *Bacillus diphtheriae* Flügge, Die Mikroorganismen, 2 Aufl., 1886, 225; *Pacinia loefleri* Trevisan, I generi e la specie delle Batteriacee, 1889, 23; Lehmann and Neumann, Bakt. Diag., 1 Aufl., *2*, 1896, 350; *Bacterium diphtheriae* Migula, Syst. d. Bakt., *2*, 1900, 499.) From Greek *diphthera*, a piece of leather; M. L., the disease diphtheria.

Common name: Diphtheria bacillus; Klebs-Loeffler bacillus.

Rods, varying greatly in dimensions, 0.3 to 0.8 by 1.0 to 8.0 microns, occurring singly. The rods are straight or slightly curved, frequently swollen at one or both ends. The rods do not, as a rule, stain uniformly with methylene blue but

show alternate bands of stained and unstained material and in addition one or more metachromatic granules which are best shown by special stains. Non-motile. Gram-positive but not intensely so in older cultures.

Gelatin colonies: Slow development. Very small, grayish, lobulate.

Gelatin stab: Slight growth on surface and scant growth in stab. No liquefaction.

Agar slant: Scant, grayish, granular, translucent growth, with irregular margin.

Blood-tellurite media: Produces gray to black colonies.

Colony forms: Smooth (S) colony form: Round and umbonate or convex, with even margin and smooth surface. Opaque when viewed by transmitted light, glistening and somewhat moist in appearance when viewed by reflected light. Colonies about 1 to 3 mm in diameter. Growth frequently slowed or inhibited by the presence of potassium tellurite in the medium.

Rough (R) colony form: Flat, margin is very irregular. Surface is pitted and very uneven. Very little light reflected from surface. Translucent when viewed by transmitted light. Colonies about 1 to 5 mm in diameter.

Intermediate colony forms: Several colony forms are found in this group since the term includes all forms between the pure S form and the pure R form. Sr forms very nearly approach the S colonies and the sR forms nearly approach the pure R forms. The SR form shows properties distinct from either the S or R forms. The colonies are 3 to 5 mm in diameter. The margin usually shows indentations. The surface is raised but not convex; it may be nearly level or show a central elevation surrounded by a concentric depression and elevation.

Dwarf (D) colony form: Colonies very small, about 0.2 mm or less in diameter. Margin round and even. Surface convex.

All of the above colony forms have been isolated from cases of diphtheria (Morton, Jour. Bact., *40*, 1940, 768 ff.).

Broth: Uniform turbidity produced by S form, pellicle produced by SR form, sediment produced by the R form.

Litmus milk: Unchanged.

Potato: No visible growth.

Blood serum: Growth grayish to cream-colored, moist, smooth, slightly raised, margin entire. May be bright yellow or occasionally reddish (Hill, Sci., *17*, 1903, 375).

Indole is not formed.

Nitrites are produced from nitrates.

All strains form acid from glucose and fructose; some strains also ferment galactose, maltose, sucrose, dextrin and glycerol.

Does not hydrolyze urea (Merkel, Cent. f. Bakt., I Abt., Orig., *147*, 1941, 398).

A highly poisonous exotoxin is produced in fluid media. This toxin represents the principal disease-producing agency of the organism. Toxin production may fail in otherwise typical strains.

A highly potent antitoxin can be produced by repeated injection of toxin into experimental animals. The antitoxin possesses both curative and protective properties.

Serological types: In a study of 250 strains of *Corynebacterium diphtheriae* Murray (Jour. Path. and Bact., *41*, 1935, 439-45) was able to classify 228 strains into 11 serological types and 22 strains remained unclassified (Morton, Bact. Rev., *4*, 1940, 196).

McLeod et al. (Jour. Path. and Bact., *34*, 1931, 667; *ibid.*, *36*, 1933, 169; Lancet, *1*, 1933, 293) describe three types which have been confirmed by other workers; these are distinguishable by colony form on McLeod's blood-tellurite medium, they are antigenically different with subtypes, there is some difference between their toxins (Etris, Jour. Inf. Dis., *50*, 1934, 220) and the severity of disease is associated with the type.

Corynebacterium diphtheriae type *gravis*

grows with dark gray, daisy-head colonies; ferments dextrin, starch and glycogen; is not hemolytic; has very few small metachromatic granules; forms a pellicle, granular deposit and there is an early reversal of pH in broth.

Corynebacterium diphtheriae type *mitis* grows in convex, black, shiny, entire colonies; no fermentation of starch and glycogen and is variable with dextrin; hemolytic; metachromatic granules are prominent; diffuse turbidity, infrequent pellicle and there is a late reversal of pH in broth.

Corynebacterium diphtheriae type *intermedius* grows a small, flat, umbonate colony with a black center and slightly crenated periphery; not hemolytic; barring of bacilli is accentuated; there is no fermentation of starch and glycogen, and is variable with dextrin; forms no pellicle, a fine granular deposit and there is no reversal of pH in broth.

Ten years of observations in all parts of the world have shown (McLeod, Bact. Rev., 7, 1943, 1) that a small percentage of strains does not correspond closely to any of these three types. Variant strains are found most frequently in regions where the diphtheria is of mild or moderate severity.

Aerobic, facultative.

Optimum temperature 34° to 36°C. Grows well at 37°C.

Source: Commonly from membranes in the pharynx, larynx, trachea and nose in human diphtheria; from the seemingly healthy pharynx and nose in carriers; occasionally from the conjunctiva and infected superficial wounds. Found occasionally infecting the nasal passages and wounds in horses. Has been described from natural diseases in fowl.

Habitat: The cause of diphtheria in man. Pathogenic to guinea pigs, kittens and rabbits. For action on other animals see Andrews et al., Diphtheria. London, 1923, 170 ff.

2. Corynebacterium pseudodiphtheriticum Lehmann and Neumann. (Bacillus der pseudodiphtherie, Loeffler, Cent. f. Bakt., *2*, 1887, 105; G. von Hofmann-Wellenhof, Wien. med. Wochenschr., *38*, 1888, 65; Lehmann and Neumann, Bakt. Diag., 1 Aufl., *2*, 1896, 361; *Bacillus pseudodiphthericus* Kruse, in Flügge, Die Mikroorganismen, 3 Aufl., *2*, 1896, 476; *Bacterium pseudodiphtheriticum* Migula, Syst. d. Bakt., *2*, 1900, 503; *Mycobacterium pseudodiphthericum* Chester, Man. Determ. Bact., 1901, 355; *Bacillus hoffmanii* (sic) Holland, Jour. Bact., *5*, 1920, 218; *Corynebacterium hoffmanii* (sic) Holland, *ibid.*, 220; *Corynebacterium pseudodiphtheriae* Holland, *ibid.*; *Corynebacterium pseudodiphthericum* Bergey et al., Manual, 2nd ed., 1925, 393.) From Greek *pseudus*, a falsehood; M. L., the disease diphtheria.

Common name: Pseudodiphtheria bacillus or Hofmann's bacillus.

Excellent historical discussions of this and related organisms are given by Bergey, Comparative Studies upon the Pseudo-diphtheria or Hofmann's Bacillus, the Xerosis Bacillus, and the Loeffler Bacillus. Contrib. from Lab. of Hyg., Univ. of Penn., No. 2, 1898, 19–54 and by Andrewes et al., Diphtheria. London, 1923, 382–388.

Rods, with rounded ends, 0.3 to 0.5 by 0.8 to 1.5 microns, fairly uniform in size, without swollen ends. Not barred but even staining interrupted by transverse, medial unstained septum; granules usually absent. Non-motile. Gram-positive.

Gelatin colonies: Small, grayish to cream-colored, smooth, homogeneous, entire.

Gelatin stab: Slight surface growth with little growth in stab. No liquefaction.

Agar colonies: Opaque, grayish to cream-colored, smooth, homogeneous, entire.

Agar slant: Moist, smooth, white to cream-colored, entire growth.

Loeffler's blood serum: As on agar.

Broth: Slightly turbid with slight, grayish sediment.

Litmus milk: Unchanged.

Potato: Slight, creamy-white, smooth, entire growth.

Indole not formed.

Nitrites produced from nitrates.

No acid from carbohydrate media.

Hydrolyzes urea (Merkel, Cent. f. Bakt., I Abt., Orig., *147*, 1941, 398).

Aerobic, facultative.

Optimum temperature 37°C.

Not pathogenic.

Source: From oral cavity of 26 out of 45 control cases.

Habitat: Normal throats.

3. **Corynebacterium enzymicum** (Mellon) Eberson. (An unusual diphtheroid bacillus, Mellon, Med. Record, New York, *81*, 1916, 240; *Bacillus enzymicus* Mellon, Jour. Bact., *2*, 1917, 297; Eberson, Jour. Inf. Dis., *23*, 1918, 29.) From Greek *en*, inside of; *zyme*, leaven; of an enzyme.

Rods, beaded and club-shaped, definitely pleomorphic, showing coccoid forms. Non-motile. Gram-positive.

Gelatin stab: Slight surface growth. No liquefaction.

Glucose agar: Bacillary form shows very small colorless colonies. Coccoid form shows heavy, yellowish-white, moist growths.

Blood agar: Same as on glucose agar.

Loeffler's blood serum: Fine, moist, confluent growth.

Glucose broth: Bacillary form shows granular sediment. Coccoid form shows diffuse, luxuriant growth.

Litmus milk: Acid, coagulated.

Potato: No growth.

Indole formation slight.

Slight production of nitrites from nitrates.

Acid from glucose, maltose, sucrose, dextrin and glycerol.

Aerobic, facultative.

Optimum temperature 37°C.

Pathogenic for rabbits, guinea pigs and mice.

Source: Lungs, blood and joints.

Habitat: From human sources so far as known.

4. **Corynebacterium xerose** (Neisser and Kuschbert) Lehmann and Neumann. (*Bacillus xerosis* Neisser and Kuschbert, Breslauer ärtzl. Ztschr., No. 4, 1883; Xerosebacillen, Kuschbert, Deutsche med. Wochnschr., *10*, 1884, 321 and 341; *Pacinia neisseri* Trevisan, I generi e le specie delle Batteriacee, 1889, 23; Lehmann and Neumann, Bakt. Diag., 2 Aufl., *2*, 1899, 405; *Bacterium xerosis* Migula, Syst. d. Bakt., *2*, 1900, 485.) From Greek *xerus*, dry.

An excellent historical discussion of this organism is given by Andrewes et al., Diphtheria. London, 1923, 377–382.

Rods, showing polar staining, occasionally club-shaped forms are seen. Non-motile. Gram-positive.

Plain gelatin colonies: Rarely develop.

Serum gelatin stab: No liquefaction.

Agar colonies: Minute, circular, almost transparent, raised, smooth, pearly white.

Agar slant: Thin, grayish, limited growth.

Loeffler's blood serum: Thin, grayish, adherent growth.

Broth: Clear, with slight, granular sediment.

Litmus milk: Unchanged.

Potato: No visible growth.

Indole not formed.

Nitrites not produced from nitrates.

Acid from glucose, fructose, galactose, maltose and sucrose.

Not pathogenic.

Aerobic, facultative.

Optimum temperature 37°C. Grows very slowly as low as 18° to 25°C (Eberson, Jour. Inf. Dis., *23*, 1918, 3).

Source: From normal and diseased conjunctiva.

Habitat: Probably identical with other species described from the skin and other parts of the body.

5. **Corynebacterium hoagii** (Morse) Eberson. (Bacillus X, Hoag, Boston Med. and Surg. Jour., *157*, 1907, 10; *Bacillus hoagii* Morse, Jour. Inf. Dis., *11*, 1912, 284; Eberson, Jour. Inf. Dis., *23*, 1918, 10.) Named for Hoag, the bacteriologist who first isolated the species.

Rods: 0.8 to 1.0 by 1.0 to 3.0 microns, occurring singly. Show polar staining in the shorter forms while the longer forms are barred and slightly club-shaped. Non-motile. Gram-positive.

Gelatin colonies: Small, dull, pale pink, entire.

Gelatin stab: Slight pink surface growth. No liquefaction.

Agar colonies: Small, pale pink, dull, granular, entire.

Agar slant: Filiform, dull, pink growth.

Broth: Turbid, with slight pink sediment.

Litmus milk: Slightly alkaline, with pink sediment.

Potato: Dull, filiform streak.

Indole not formed.

Nitrites not produced from nitrates.

Acid from glucose and sucrose but not maltose.

Blood serum: Dull, filiform, pink streak.

Aerobic.

Optimum temperature 30°C.

Source: From the throat. Air contamination of cultures.

Habitat: Unknown.

6. **Corynebacterium acnes** (Gilchrist) Eberson. (*Bacillus acnes* Gilchrist, Johns Hopkins Hosp. Repts., 9, 1901, 425; *Actinomyces acnes* Gilchrist, *ibid.*, 425; Eberson, Jour. Inf. Dis., *23*, 1918, 10; *Fusiformis acnes* Holland, Jour. Bact., *5*, 1920, 233; *Propionibacterium acnes* Douglas and Gunter, Jour. Bact., *52*, 1946, 22.) From M. L. *acne*, the disease acne.

Rods, vary in dimensions, usually 0.5 by 0.5 to 2.0 microns, sometimes slightly club-shaped. Show alternate bands of stained and unstained material. Non-motile. Gram-positive.

Growth in culture media very feeble.

Best growth occurs in shake cultures with soft, slightly acid, glucose agar.

Agar slant: Very small, circular transparent colonies which may later become rose-colored.

Loeffler's blood serum: Small, grayish colonies, which may later become rose-colored.

Broth: Clear.

Litmus milk: Soft coagulum.

Potato: No growth in aerobic cultures, but pink streak in anaerobic cultures.

Indole not formed.

Nitrites produced from nitrates.

Acid from glucose, sucrose (slight), maltose, mannitol and inulin. Produces propionic acid (Douglas and Gunter, *loc. cit.*).

Catalase produced.

Microaerophilic to anaerobic.

Optimum temperature 35° to 37°C.

Pathogenic for mice and gives rise to characteristic lesions.

Source: From acne pustules.

Habitat: Sebaceous glands, hair follicles and acne pustules.

NOTES: Even before 1901, several authors reported finding bacteria in acne pustules which were evidently diphtheroid in nature. Unna (Monatshefte f. prakt. Derm., *13*, 1891, 232) found an organism in acne pustules which he gave the name of Flaschenbacillus. Hodara (Monatshefte f. prakt. Derm., *18*, 1894, 586) reported the presence of two types of bacteria in acne lesions, the second of which he called Flaschenkugelbacillus. Sabouraud (Ann. Inst. Past., *11*, 1897, 134) gave a more accurate description of these diphtheroids which he reported to need an acid medium for growth. He called this bacterium, bacille de séborrhée grasse (*Bacillus sabouraudi* Neveu-Lemaire, Précis Parasitol. Hum., 5th ed., 1921, 24).

Additional anaerobic species will be found in the appendix. These are *Corynebacterium typhi* which Eberson (*loc. cit.*, 19) and Hewlett (Med. Res. Council, Syst. of Bact., London, *5*, 1930, 145) regard as practically identical with *Corynebac-*

terium acnes, and eleven species listed by Prévot (Manual de Classification et de Détermination des Bactéries Anaérobies. Monographie, Inst. Past., Paris, 1940, 199–204) as follows: *Corynebacterium diphtheroides*, *C. avidum*, *C. renale cuniculi*, *C. lymphophilum*, *C. hepatodystrophicans*, *C. parvum*, *C. anaerobium*, *C. granulosum*, *C. adamsoni*, *C. liquefaciens*, and *C. pyogenes bovis*.

7. **Corynebacterium pyogenes** (Glage) Eberson. (*Bacillus liquefaciens pyogenes bovis* Lucet, Ann. Inst. Past. *7*, 1893, 327; *Bacillus liquefaciens pyogenes* Lucet, *ibid.*, 327; *Bacillus liquefaciens* Lucet, *ibid.*; Bakterium der multipler Abszessbildung der Schweine, Grips, Ztschr. f. Fleisch- u. Milchhyg., *8*, 1898, 166; *Bacillus pyogenes bovis* Künnemann, Arch. f. wiss. u. prakt. Tierheilk., *29*, 1903, 128; *Bacillus pyogenes* Glage, Ztschr. f. Fleisch- u. Milchhyg., *13*, 1903, 166; not *Bacillus pyogenes* Lucet, Ann. Inst. Past., *7*, 1893, 327; *Bacillus pyogenes suis* Lehmann and Neumann, Bakt. Diag., 4 Aufl., *2*, 1907, 394; *Bacterium hyopyogenes* Lehmann and Neumann, Bakt. Diag., 4 Aufl., *2*, 1907, 394; *Bacterium pyogenes suis* Lehmann and Neumann, Bakt. Diag., 7 Aufl., *2*, 1927, 499; *Bacterium pyogenes* Ward, Jour. Bact., *2*, 1917, 519; not *Bacterium pyogenes* Chester, Man. Determ. Bact., 1901, 184; Eberson, Jour. Inf. Dis., *23*, 1918, 5; not *Corynebacterium pyogenes* Lewandowsky, Cent. f. Bakt., I Abt., Orig., *36*, 1904, 473; *Corynebacterium pseudopyogenes* Ochi and Zaizen, Jour. Jap. Soc. Vet. Sci., *15*, 1936, 12 and *16*, 1937, 8.) From Greek *pyum*, pus; *gignomai*, producing.

For description see Brown and Orcutt, Jour. Exp. Med., *32*, 1920, 244.

Rods: 0.2 by 0.3 to 2 microns in length. Smallest forms appear as scarcely visible points (common in old abscesses). Chains formed. Club forms may be present. Non-motile. Gram-positive.

Serum gelatin: Liquefaction.

No growth on ordinary agar.

Serum agar: Minute colonies after 36 to 48 hours. Surface colonies may increase to 3 mm in diameter. Colonies smoky brown by transmitted light and bluish-white by reflected light.

Bovine blood serum slants: Pit-like or more general areas of liquefaction.

Serum bouillon: Cloudy with fine flocculent grayish flakes that form a sediment like a streptococcus culture.

Milk: Coagulation after 48 hours at 37°C, with acid at bottom of tube. Separation of whey and peptonization.

Nitrites not produced from nitrates (Merchant, Jour. Bact., *30*, 1935, 108).

Indole not formed.

Acid formed in serum bouillon from glucose, sucrose, lactose, and xylose but not from raffinose, inulin, mannitol and salicin.

Beta hemolytic, not hemoglobinophilic though growth is favored by proteins as egg albumen, serum or blood (Brown and Orcutt, *loc. cit.*).

Optimum temperature 37°C. Growth range 20° to 40°C.

Intravenous injection of rabbits fatal.

Aerobic as well as anaerobic growth.

Source: From bovine pus.

Habitat: Found in abscesses in cattle, swine and other domestic animals.

8. **Corynebacterium renale** (Migula) Ernst. (*Bacillus renalis bovis* Bollinger, in Enderlen, Zeit. f. Tiermed., *17*, 1890, 346; *Bacillus pyelonephritis boum* (sic) Höflich, Monatsh. f. prakt. Tierheilk., *2*, 1891, 356; *Bacterium renale* Migula, Syst. d. Bakt., *2*, 1900, 504; *Bacillus renalis* Ernst, Cent. f. Bakt., I Abt., Orig., *39*, 1905, 550; Ernst, *ibid.*, *40*, 1905, 80; *Corynebacterium renalis bovis* Ernst, *ibid.*, 82.) From Latin *renalis*, kidney.

Description largely taken from Jones and Little, Jour. Exp. Med., *44*, 1926, 11.

Rods: 0.7 by 2 to 3 microns. Non-motile. Usually in masses, rarely single. Bacteria from tissues not as pleomorphic as those from the earlier transfer cultures although many show polar granules or swollen ends. Cultures grown in broth show coccoid forms and beaded rods with swollen ends. Gram-positive.

Gelatin: Grows poorly if at all. No liquefaction.

Agar: Small punctiform colonies.

Agar slants: Raised, grayish-white, and dry growth (Jones and Little). Others say cream-colored and moist.

Blood serum slants: Fine gray punctiform colonies in 24 hours at 37°C which are a little larger than on agar. Streak scarcely 1 mm in width. Glistening and slimy in fresh cultures. No liquefaction.

Litmus milk: Reduction and coagulation from the bottom. Slow digestion, becoming alkaline.

Broth: Sediment at end of 2 days with clear bouillon above.

Potato: Growth grayish-white; later, becoming a dingy yellow, turning the potato brown.

Acid from glucose. No acid from lactose, sucrose, maltose and mannitol. Some strains ferment fructose and mannose (Merchant, Jour. Bact., *30*, 1935, 109).

Shows a close serological relationship with *Corynebacterium pseudotuberculosis* (Merchant). Anaerobic.

Not pathogenic for laboratory animals. No toxin produced.

Optimum temperature 37°C.

Source: Found in pyelonephritis in cattle.

Habitat: Occurs in purulent infections of the urinary tract in cattle, sheep, horses and dogs.

9. **Corynebacterium pseudotuberculosis** (Buchanan) Eberson. (Nocard, Bull. de la Soc. Centr. de méd. Vet., 1885, 207; Pseudotuberculose-Bakterien, Preisz, Cent. f. Bakt., *10*, 1891, 568; *Bacillus pseudotuberculosis ovis* Lehmann and Neumann, Bakt. Diag., 1 Aufl., *2*, 1896, 362; *Bacillus pseudotuberculosis* Buchanan, Veter. Bact., Phila., 1911, 238; not *Bacillus pseudotuberculosis* Eisenberg, Bakt. Diag., 3 Aufl., 1891, 294; Eberson, Jour. Inf. Dis., *23*, 1918, 10; *Corynebacterium ovis* Bergey et al., Manual, 1st ed., 1923, 388; not *Corynebacterium pseudotuberculosis* Bergey et al., Manual, 2nd ed., 1925, 394; *Corynebacterium pseudotuberculosis bovis* (an evident typographical error) Thomson and Thomson, Ann. Pickett-Thomson Res. Lab., *2*, 1926, 132; *Corynebacterium pseudotuberculosis ovis* Hauduroy et al., Dict. d. Bact. Path., 1937, 159; *Corynebacterium preisz-nocardi* Hauduroy et al., *ibid.*, 159.) From Greek *pseudus*, a falsehood; Latin *tuberculum*, a small nodule; M.L., false tuberculosis.

Common name: Preisz-Nocard bacillus.

Slender rods: 0.5 to 0.6 by 1.0 to 3.0 microns, staining irregularly and showing clubbed forms. Non-motile. Gram-positive.

Gelatin colonies: Slight development.

Gelatin stab: No liquefaction.

Agar colonies: Thin, cream-colored to orange, folded, serrate, dry.

Loeffler's blood serum: Small, yellow, serrate colonies. No liquefaction.

Broth: No turbidity. Granular sediment. Pellicle formed (Carne, Jour. Path. and Bact., *49*, 1939, 316).

Litmus milk: Unchanged.

Potato: No growth.

Nitrites not produced from nitrates.

Acid from glucose, fructose, galactose, mannose, sucrose, lactose, maltose and dextrin. Some strains attack xylose.

Causes caseous lymphadenitis in sheep and ulcerative lymphangitis in horses. Forms an exotoxin.

Shows a close serological relationship with *Corynebacterium renale* (Merchant, Jour. Bact., *30*, 1935, 109).

Aerobic, facultative.

Optimum temperature 37°C.

Source: From necrotic areas in the kidney of a sheep.

Habitat: Found in caseous lymphadenitis in sheep and ulcerative lesions in horses, cattle and other animals.

10. **Corynebacterium kutscheri** (Migula) Bergey et al. (*Bacillus pseudotuberculosis murium* Kutscher, Ztschr. f. Hyg., *18*, 1894, 338; *Bacillus pseudotuberculosis murium* Lehmann and Neumann, Bakt. Diag., 1 Aufl., *2*, 1896,

362; *Bacterium kutscheri* Migula, Syst. d. Bakt., *2*, 1900, 372; *Mycobacterium pseudotuberculosis* Chester, Manual Determ. Bact., 1901, 355; *Corynebacterium murium* Bergey et al., Manual, 1st ed., 1923, 386; Bergey et al., Manual, 2nd ed., 1925, 395.) Named for the bacteriologist Kutscher, who first isolated the species.

Rods with pointed ends, staining irregularly. Non-motile. Gram-positive.

Gelatin colonies: Small, white, translucent.

Gelatin stab: No growth on surface. White, filiform growth in stab. No liquefaction.

Agar colonies: Small, thin, yellowish-white, translucent, serrate.

Agar slant: Thin, white, translucent.

Loeffler's blood serum: Abundant growth. Not peptonized.

Broth: Slight turbidity. Crystals of ammonium magnesium phosphate are formed.

Litmus milk: Unchanged.

Potato: No growth.

Indole not formed.

Nitrites not produced from nitrates.

Aerobic, facultative.

Optimum temperature 37°C.

Source: From cheesy mass in lung of mouse.

11. **Corynebacterium murisepticum** v. Holzhausen. (Cent. f. Bakt., I Abt., Orig., *105*, 1927–28, 94.) From Latin *mus, muris*, a mouse; Greek *septicus*, putrefying, septic.

Slender rods: 1.2 to 1.5 microns in length, with polar granules. Grow out into long filaments. Non-motile. Gram-positive.

Gelatin stab: Feeble growth, with fimbriate outgrowth along line of puncture.

Egg glycerol broth: Good growth.

Loeffler's blood serum: Good growth.

Broth: Turbid.

Litmus milk: Acid. No coagulation.

Potato: Good growth.

Indole not formed.

Nitrates not reported.

Acid from glucose, fructose, galactose, maltose, lactose, sucrose, inulin and mannitol. Arabinose and isodulcitol are not attacked.

Hydrogen sulfide formed.

Pathogenic for mice.

Aerobic, facultative.

Optimum temperature 37°C.

Habitat: Septicemia in mice.

12. **Corynebacterium bovis** Bergey et al. (*B. pseudodiphtheria*, Bergey, The Source and Nature of Bacteria in Milk. Penn. Dept. Agr. Bull. 125, 1904, 11; Bergey et al., Manual, 1st ed., 1923, 388.) From Latin *bos, bovis*, ox; of cattle.

Rods, slender, barred, clubbed, 0.5 to 0.7 by 2.5 to 3.0 microns. Non-motile. Gram-positive.

Gelatin stab: Slight, gray, flat surface growth.

Agar colonies: Circular, gray, slightly raised, radiate, undulate, dry.

Agar slant: Thin, gray, filiform, dry growth.

Broth: Slight granular sediment.

Litmus milk: Slowly becoming deeply alkaline.

Potato: No growth.

Indole not formed.

Nitrites not produced from nitrates.

No acid from carbohydrate media.

Blood serum: Thin, gray, filiform growth.

Causes rancidity in cream. Weakly lipolytic on tributyrin agar (Black, Jour. Bact., *41*, 1941, 99).

Optimum temperature 37°C.

Source: In fresh milk drawn directly from the cow's udder.

Note: Miss Alice Evans (personal communication) states that the organism from the udder which she described as *Bacterium lipolyticus* (sic) (*Bacillus abortus* var. *lipolyticus* Evans, Jour. Inf. Dis., *18*, 1916, 459; *Bacterium abortus* var. *lipolyticus* Evans, Jour. Bact., *2*,

1917, 185; Evans, Jour. Inf. Dis., *22*, 1918, 576; not *Bacterium lipolyticum* Huss, Cent. f. Bakt., II Abt., *20*, 1908, 474; *Alcaligenes lipolyticus* Pacheco, Revista da Sociedade Paulista de Med. Vet., *3*, 1933, 9) was probably a *Corynebacterium*. This is also regarded as probable by Steck (Die latente Infektion der Milchdrüse, Hanover, 1930) and by Bendixen (Ztschr. f. Infektionskrankh. d. Haustier., *43*, 1933, 106). Miss Evans also indicates that it is probable that the organism described by Bergey first in 1904 (*loc. cit.*) and later in the first edition of the Manual as *Corynebacterium bovis* was the same organism. This is further confirmed by Black (Jour. Bact., *41*, 1941, 99). A description of *Bacterium lipolyticum* Evans will be found in the Manual, 5th ed., 1939, 803.

13. **Corynebacterium equi** Magnussen. (Magnusson, Arch. f. Tierheilk. *50*, 22; *Corynebacterium pyogenes (equi)* Meissner and Wetzel, Deutsche Tierarztl. Wehnschr., *31*, 1923, 449; *Corynebacterium (pyogenes) equi roseum* Lütji, *ibid.*, 561; *Mycobacterium equi* Jensen, Proc. Linn. Soc. New So. Wales, *59*, 1934, 33; *Corynebacterium magnussonholth* Plum, Cornell Vet., *30*, 1940, 15; *Corynebacterium purulentus* Holtman, Jour. Bact., *49*, 1945, 161.) From Latin *equus*, horse.

Description from Dimock and Edwards, Kentucky Agri. Exper. Stat., Bull. 333, 1932; Bruner and Edwards, *ibid.*, Bull. 414, 1941; Merchant, Jour. Bact., *30*, 1935, 95; and Brooks and Hucker, Jour. Bact., *48*, 1944, 309.

Rods variable according to medium. Coccoid and ellipsoidal cells to rather long curved and sometimes clubbed forms. The latter are especially apt to occur in liquid media. Non-motile. Gram-positive.

Gelatin stab: Good growth. No liquefaction.

Agar colonies: Usually moist, smooth and glistening, tan to yellow (Brooks and Hucker, *loc. cit.*, p. 300) or pink to red chromogenesis (Merchant, *loc. cit.*, p. 107).

Agar slant: Moist heavy growth which may run down the slant (Dimock and Edwards, *loc. cit.*, p. 322).

Broth: Turbid with no pellicle and little sediment (Dimock and Edwards, *loc. cit.*, p. 322). Pellicle and final pH alkaline (Brooks and Hucker, *loc. cit.*, p. 309). Branched cells occur in 6 to 8 hour cultures in broth.

Loeffler's blood serum: Good growth with tan to yellow chromogenesis. No liquefaction.

Coagulated egg yolk: Vigorous salmon-pink growth. Dryer than on agar, resembling wrinkled growth of tubercle bacillus after two weeks.

Litmus milk: No change to slightly alkaline.

Potato: Abundant growth, usually tan, yellow or pink.

Indole not formed.

Hydrogen sulfide produced on appropriate media.

Nitrites produced from nitrates. No ammonia produced.

No acid from carbohydrate media. However, glucose stimulates growth.

Sodium hippurate: Not hydrolyzed.

Esculin: Not hydrolyzed.

No exotoxin demonstrated in filtrate of broth cultures.

No or slight hemolysis of horse blood.

Not pathogenic for laboratory animals.

Aerobic.

Temperature relations: Optimum 25° to 37°C. Maximum 37° to 45°C. Minimum 7° to 18°C.

Source: Originally isolated from infectious pneumonia of foals.

Habitat: Found in spontaneous pneumonia of foals and other infections in horses. Also in swine, cattle and buffaloes.

NOTE: Jensen (*loc. cit.*, 33) regards four cultures of soil bacteria isolated in Australia as identical with this organism.

Because of the acid-fast staining of the cells, especially when grown in milk for 3 to 7 days, he places this species in the genus *Mycobacterium*. Most cocci retain the stain completely, while the rods take the counterstain. Jensen thinks the organism a widespread soil saprophyte which under certain conditions acquires pathogenic properties. He points out the close relationship of this organism to *Bacterium aurantium-roseum* Honig (Mededeel. Deli Proefstat. te Medan, *7*, 1912, 223) isolated from fermenting tobacco. He also regards this species as closely related to *Mycobacterium coeliacum* Gray and Thornton. Red strains seem to be much like *Bacillus rubropertinctus* Hefferan and *Micrococcus* (*Staphylococcus*) *erythromyxa* Zopf.

14. **Corynebacterium paurometabolum** Steinhaus. (Jour. Bact., *41*, 1941, 763 and 783.) From Greek *paurus*, little; *metabole*, change or little action.

Rods: 0.5 to 0.8 by 1.0 to 2.5 microns, occurring singly, in pairs and in masses. Metachromatic granules present. Non-motile. Gram-positive.

Gelatin stab: Slow liquefaction at surface.

Agar colonies: White to gray, entire, circular, small, dry, somewhat granular.

Agar slant: Filiform to arborescent, thick, granular growth.

Broth: Abundant granular sediment but no turbidity. Pellicle.

Litmus milk: Alkaline.

Potato: Thick, raised, dry, granular, profuse, gray to light cream-colored growth.

Indole not produced.

Slight production of hydrogen sulfide.

Nitrites not produced from nitrates.

No action on the following carbohydrates: Glucose, lactose, sucrose, maltose, fructose, mannitol, galactose, arabinose, xylose, dextrin, salicin, raffinose, trehalose, sorbitol, inulin, dulcitol, glycerol, rhamnose, adonitol, mannose, esculin and inositol.

Aerobic.

Slight alpha hemolysis.

Non-pathogenic for guinea pigs.

A special semi-solid medium, the main nutritive constituents of which were proteose peptone, rabbit serum, gelatin, minced rabbit kidney and carbohydrates, was used for the original isolation. An incubation period of 4 to 7 days at 26°C was necessary for the initial isolation. Subsequent transfers to ordinary beef-infusion agar grew out in 24 to 48 hours.

Source: From media inoculated with the mycetome and ovaries of the bedbug, *Cimex lectularius* L. A very similar diphtheroid strain was isolated from the alimentary tract of the bagworm, *Thyridopteryx ephemeraeformis* Haw.

Habitat: Distribution in nature unknown.

*15. **Corynebacterium insidiosum** (McCulloch) Jensen. (*Aplanobacter insidiosum* McCulloch, Phytopath., *15*, 1925, 497; *Bacterium insidiosum* Stapp, in Sorauer, Handb. der Pflanzenkr., *2*, 5 Aufl., 1928, 178; *Phytomonas insidiosa* Bergey et al., Manual, 3rd ed., 1930, 278; Jensen, Proc. Linnean Soc. of New So. Wales, *59*, 1934, 41.) From Latin *insidiosus*, deceitful, dangerous.

Also see McCulloch, Jour. Agr. Res., *33*, 1926, 502.

Rods: 0.4 to 0.5 by 0.7 to 1.0 micron. Capsules present. Non-motile. Gram-positive.

Gelatin: Slow liquefaction.

Beef agar colonies: Pale yellow, circular, smooth, shining; edges entire; viscid. Blue granules found on the medium.

Milk: Coagulated after 16 to 20 days. No digestion. An apricot yellow sediment is deposited on the walls of the tube.

* Descriptions of Species nos. 15 to 20 inclusive prepared by Professor Walter H. Burkholder, Ithaca, New York.

Nitrites not produced from nitrates.

Indole not formed.

No H_2S produced.

Acid from glucose, sucrose, lactose and glycerol.

Moderate diastatic action.

Grows in 5 per cent salt.

Optimum temperature 23°C. Maximum 31°C.

Aerobic.

Distinctive character: Bluish granules produced in culture.

Source: Isolated from diseased alfalfa plants.

Habitat: Vascular pathogen of alfalfa, *Medicago sativa*.

NOTE: Jensen (*loc. cit.*) regards this species as being almost identical with *Corynebacterium helvolum* Kisskalt and Berend. He isolated one strain from grass soil which he regards as a saprophytic strain of this species. Jensen emphasized the angular arrangement of young cells grown on agar and potato. A faint indication of reduction of nitrates and of diastatic action was obtained. He also reports a weak proteolysis of milk. Optimum reaction is given as pH 5.6 to 6.8. A slimy variant of the soil strain was isolated from an old culture in glucose broth which seemed to agree better in its characteristics with the organism as described by Jones and McCulloch than did the non-slimy strains.

15a. *Corynebacterium insidiosum* var. *saprophyticum* Jensen (*loc. cit.*, 42) is based on a non-infectious soil strain. This grew more vigorously with less definite yellow pigment on nutrient agar than the pathogenic strain. Blue-violet, insoluble pigment near edge of growth on glucose agar; no blue pigment on potato; no coagulation of milk; higher temperature maximum and more resistance to acid reaction than the pathogenic strains. From grass soil in Australia.

16. Corynebacterium sepedonicum (Spiekermann and Kotthoff) Skaptason and Burkholder. (*Bacterium sepedonicum nomen nudum* Spiekermann, Ill. Landw. Zeitung, *33*, 1913, 680; *Bacterium sepedonicum* Spiekermann and Kotthoff, Landw. Jahr., *46*, 1914, 674; *Aplanobacter sepedonicum* Erw. F. Smith, Intro. Bact. Dis. of Plants, 1920, 207; *Phytomonas sepedonica* Magrou, in Hauduroy et al., Dict. d. Bact. Path., Paris, 1937, 411; Skaptason and Burkholder, Phytopath., *32*, 1942, 439.) From Greek *sepedonicus*, putrefactive.

Description from Stapp (Ztschr. f. Par., *5*, 1930, 756).

Rods: 0.3 to 0.4 by 0.8 to 1.0 micron. Pleomorphic. Non-motile. Gram-positive.

Gelatin: Liquefaction slight.

Agar colonies: Thin, smooth, translucent, glistening, whitish, 2 to 3 mm in diameter.

Broth: Weak growth. No pellicle. Light sediment.

Litmus milk: Little change in 6 weeks, after which litmus is reduced.

Indole not formed.

No H_2S production or feeble.

Glucose, galactose, fructose, arabinose, xylose, mannitol, glycerol and dulcitol are utilized.

Starch hydrolysis light.

Grows in 4 per cent salt.

Optimum temperature 20° to 23°C. Maximum temperature 31°C. Minimum 4°C.

Distinctive characters: Differs from *Corynebacterium michiganense*, in that it is white to cream-colored on various media and has a lower optimum temperature. *Corynebacterium michiganense* does not infect potatoes.

Source: Stapp used 17 cultures isolated from diseased potatoes.

Habitat: Causes ring rot of potato tubers in Germany.

17. Corynebacterium michiganense (Erw. Smith) Jensen. (*Bacterium michiganense* Erw. Smith, Science, *31*, 1910, 794; *Pseudomonas michiganensis* Stevens, The Fungi which Cause Plant

Diseases, 1913, 30; *Aplanobacter michiganense* Erw. Smith, Bacteria in Rel. to Plant Dis., *3*, 1914, 161; *Phytomonas michiganensis* Bergey et al., Manual, 1st ed., 1923, 191; Jensen, Proc. Linnean Soc. of New So. Wales, *59*, 1934, 47; *Erwinia michiganeae*, incorrectly attributed to Bergey by Jensen, *loc. cit.*, 47.) Latinized, of Michigan, where the disease produced by this pathogen was first reported.

Description from Bryan, Jour. Agr. Res., *41*, 1930, 825.

Rods: 0.6 to 0.7 by 0.7 to 1.2 microns. Non-motile. Capsules. Gram-positive. Characteristic angular growth with branching and club-shaped cells (Jensen, *loc. cit.*).

Beef agar colonies: Growth slow, mustard yellow, smooth, glistening, butyrous.

Chromogenesis: Develops yellowish-brown, light ochre-yellow to sepia brown colors on suitable media (Jensen, *loc. cit.*).

Gelatin: Slow liquefaction.

Broth: Turbidity slow and moderate.

Milk: Slow coagulation. No peptonization.

Nitrites not produced from nitrates.

Utilizes peptone, but not ammonia, nitrite, nitrate, tyrosine, asparagine or glutamic acid (Mushin, Austral. Jour. Exp. Biol. and Med., *16*, 1938, 326).

Indole not produced.

No H_2S produced.

Acid from glucose, sucrose, galactose, fructose, maltose, and slight acid from lactose, glycerol and mannitol.

Starch: Very weak diastatic action.

No growth in 3 per cent salt.

Optimum temperature 25° to 27°C. Maximum, 33°C. Minimum, 1°C.

Aerobic.

Source: From the bacterial canker of tomato.

Habitat: Pathogenic on tomato.

17a. ***Corynebacterium michiganense* var. *saprophyticum*** **Jensen (*loc. cit.*, 48). Grows more rapidly and with more moist** growth, has a higher temperature maximum and stronger proteolytic activity than the pathogenic strains. From grass soil in Australia.

18. **Corynebacterium rathayi** (Erw. Smith) Dowson. (*Aplanobacter rathayi* Erw. Smith, Science, *38*, 1913, 926, and Bact. in Rel. to Plant Dis., *3*, 1914, 155; *Phytomonas rathayi* Bergey et al., Manual, 1st ed., 1923, 192; *Bacterium rathayi* Stevens, Fungus Dis. of Plants, 1925, 21; Dowson, Brit. Myc. Soc. Trans., *25*, 1942, 313.) Named for E. Rathay, the Austrian plant pathologist who first isolated the species.

Rods: 0.6 to 0.75 by 0.75 to 1.5 microns. Non-motile. Not acid-fast. Capsules. Gram-positive.

Gelatin: Slow liquefaction after 7 weeks.

Agar colonies: Small, yellow, slow-growing.

Milk: Growth slow. Yellow ring.

Litmus milk: Alkaline and reduced.

Nitrites are produced from nitrates.

Potato plugs: Good, yellow, viscid growth.

Acid but no gas from glucose, sucrose and lactose.

Cohn's solution: No growth.

Heavy inoculum necessary in media.

Source: Isolated from slimy heads of *Dactylis glomerata* by E. Rathay in Austria.

Habitat: Pathogenic on *Dactylis glomerata*.

NOTE: *Bacillus mucilaginosus koeleriae* Aujeszky, Botanikai Kozlemenyek, *13*, (Foreign Supl. 41), 1914, 88; *Pseudomonas mucilaginosus koeleriae* Moesz, Schedis ad Flora Hungarica Exs. Cent. IV, No. 301, Sect. Bot. Mus. Nat. Hung., Budapest, 1915. The description of the bacterium is possibly that of the saprophyte, *Pseudomonas fluorescens*, but the description of the disease is that caused by *Corynebacterium rathayi*. The specimen *in schedis* is a head of grain that appears to be infected with *Corynebacterium rathayi*.

19. **Corynebacterium agropyri** (O'Gara) *comb. nov.* (*Aplanobacter agropyri* O'Gara, Phytopath., *6*, 1916, 343; *Phytomonas agropyri* Bergey et al., Manual, 1st ed., 1923, 190; *Bacterium agropyri* Stapp, in Sorauer, Handbuch d. Pflanzenkrankheiten, 5 Aufl., *2*, 1928, 37.) From Greek *agros*, field and *puros*, wheat; M. L. *Agropyron*, wheat grass.

Rods: 0.4 to 0.6 by 0.6 to 1.1 microns. Capsules. Non-motile. Gram-variable.

Gelatin: No liquefaction.

Nutrient agar slant: Meager, yellow, very viscid growth.

Broth: Light clouding with yellow precipitate.

Milk: Little changed. Yellow sediment formed.

Nitrites are produced from nitrates.

Acid but no gas from glucose, lactose, sucrose and glycerol.

Starch: Hydrolysis feeble.

Optimum temperature 25° to 28°C.

This species is very similar to and may be identical with *Corynebacterium rathayi* Dowson.

Source: From slimy heads of wheat grass.

Habitat: Found on wheat grass, *Agropyron smithii*.

20. **Corynebacterium fascians** (Tilford) Dowson. (*Phytomonas fascians* Tilford, 54th Rept. Ohio Agr. Exp. Sta. Bull. 561, 1936, 39; Jour. Agr. Res., *53*, 1936, 393; Unnamed pathogen, Lacey, Ann. Appl. Biol., *23*, 1936, 308; Dowson, Brit. Myc. Soc. Trans., *26*, 1942, 313.) From Latin *fascio*, producing a fasciation.

Rods: 0.5 to 0.9 by 1.5 to 4.0 microns. Non-motile. Gram-positive.

Gelatin: No liquefaction.

Potato-glucose agar colonies: Light cream-colored colonies appear after 72 hours. Punctiform, circular, later cadmium yellow to deep chrome.

Nutrient agar slant: After one week streak is filiform, flat, dull to glistening, smooth, opaque, cream-colored, and butyrous.

Broth: Slightly turbid. Fragile pellicle with distinct rim.

Milk: Litmus becomes blue. Other changes slight.

Nitrites are produced from nitrates.

Indole not formed.

Hydrogen sulfide is produced.

Acid but no gas from glucose, galactose, fructose, mannose, arabinose, xylose, maltose, sucrose, glycerol, mannitol and dextrin. No acid from rhamnose, lactose, raffinose and inulin.

Starch not hydrolyzed.

Grows in 8 per cent salt.

Optimum temperature 25° to 28°C.

Aerobic.

Source: Described from 15 single cell isolates from fasciated growths on sweet peas.

Habitat: Pathogenic on sweet pea, chrysanthemum, geranium, petunia, tobacco, etc.

21. **Corynebacterium helvolum** (Zimmerman) Kisskalt and Berend. (*Bacillus helvolus* Zimmermann, Bakt. unserer Trink- u. Nutzwässer, Chemnitz, *1*, 1890, 52; *Bacterium helvolum* Lehmann and Neumann, Bakt. Diag., 1 Aufl., *2*, 1896, 254; Kisskalt and Berend, Cent. f. Bakt., I Abt., Orig., *81*, 1918, 446; *Flavobacterium helvolum* Bergey et al., Manual, 1st ed., 1923, 114.) From Latin *helvus*, of a light bay color.

Original description supplemented from Jensen, Proc. Linn. Soc. New So. Wales, *59*, 1934, 37.

Rods: 0.5 by 1.0 micron, occurring singly. Show angular arrangement due to snapping division. Variable in morphology. Non-motile. Gram-positive.

Gelatin colonies: Small, circular, yellowish-gray. Liquefaction.

Gelatin stab: Slight development along the stab. Napiform liquefaction.

Agar colonies: Circular, pale yellow, smooth, slightly convex.

Agar slant: Pale yellow, plumose to spreading, moist, undulate.

Milk agar: Growth fair to very abun-

dant, white to pale yellow. Some strains form a pink pigment. Proteolytic zones clear and broad after 4 days.

Asparagine agar: Scant to good growth, smooth, glistening, white and cream-colored to lemon-yellow or even dull pink.

Broth: Turbid, with gray ring and yellowish sediment. After four days the sediment contains long, curved and branching rods. May resemble small mycelia.

Litmus milk: Slightly acid, with soft coagulum, becoming alkaline; peptonized. Litmus reduced.

Potato: Pale yellow, moist, plumose growth, becoming rough, dull. Slimy variants noted in one strain. A myceloid variant with dry wrinkled growth was found in another strain.

Indole not formed.

Nitrites not produced from nitrates.

Acid from glucose, glycerol and mannitol. Usually from arabinose, sucrose, galactose, fructose.

Aerobic, facultative.

Hydrogen sulfide produced on appropriate media.

Optimum temperature 25°C. Usually grows at 37°C.

Source: Originally isolated from water.

Habitat: A common soil *Corynebacterium*.

22. **Corynebacterium fimi** (McBeth and Scales) Jensen. (*Bacterium fimi* McBeth and Scales, Bur. of Plant Ind., U. S. Dept. Agr., Bull. 266, 1913, 30; *Cellulomonas fimi* Bergey et al., Manual, 1st ed., 1923, 166; *Bacillus fimi* Holland, Jour. Bact., *5*, 1920, 218; Jensen, Proc. Linn. Soc. New So. Wales, *59*, 1934, 48.) From Latin *fimus*, dung.

Description from Jensen (*loc. cit.*) who studied an authentic strain.

Rods present typical diphtheroid appearance with angular arrangement, 0.4 to 0.5 by 1.2 to 2.5 microns. Many longer, rregular, curved, club-shaped and branching cells on Sabouraud's (whey) agar. Non-motile. Gram-negative (McBeth and Scales). Gram-variable like some other corynebacteria (Jensen).

Gelatin colonies: Small, round, becoming lobate. Slow liquefaction.

Gelatin stab: Granular yellow growth. Infundibuliform liquefaction.

Cellulose agar colonies: Circular, raised, smooth, glistening, gray, entire.

Agar slant: Smooth, glistening, white to lemon-yellow growth.

Glucose and Sabouraud's agar: Growth less abundant and cream-colored.

Asparagine agar: Very scant growth, narrow, thin, glistening, white.

Broth: Uniform turbidity, soft cream-colored to yellow sediment after 3 weeks.

Litmus milk: Coagulated at 3 weeks at 37°C. Not at 28° to 30°C. Faintly acid.

Potato: Slow cream-colored to yellow growth.

Indole is formed.

Nitrites are produced from nitrates.

Ammonia is produced in peptone solutions.

Diastatic action doubtful.

Acid from glucose, fructose, arabinose, xylose, maltose, lactose, sucrose, raffinose, melezitose, dextrin, starch, salicin and glycerol. None or feebly produced from mannitol and dulcitol.

Causes rapid disintegration of cellulose (filter paper) in a 0.5 per cent peptone solution.

Aerobic, facultative.

Optimum temperature 20°C (McBeth and Scales). Better growth at 37°C than at 28° to 30°C (Jensen).

Source: Probably isolated from soil. Found in soils of Southern California (McBeth, Soil Sci., *1*, 1916, 443).

Habitat: Soil.

Bacterium liquatum McBeth and Scales (McBeth and Scales, Bur. Plant Ind., U. S. Dept. Agr., Bull. 266, 1913, 32; *Cellulomonas liquata* Bergey et al., Manual, 1st ed., 1923, 166) should be regarded as identical with this species as the only significant difference reported between the two species by the original authors was that *Bacterium liquatum* produced a

yellow chromogenesis more readily. This, however, does not appear to have occurred any more frequently than took place with the authentic culture of *Bacterium fimi* when tested by Jensen (*loc. cit.*).

23. **Corynebacterium tumescens** Jensen. (Jensen, Proc. Linn. Soc. New So. Wales, *59*, 1934, 45.) From Latin *tumescens*, swollen.

Rods show characteristic cytomorphosis in glucose agar, Sabouraud's (whey) agar and milk agar. Cells after 18 to 24 hours at 28° to 30°C are curved, often branched, show an angular arrangement. 0.5 to 0.8 by 2.5 to 6.0 microns. After 2 to 3 days many spherical to club-shaped cystites (3 microns in diameter) arise as local swellings of the rods. Staining intensely at first, they gradually change into large, irregular, poorly stained ghost cells which show deeply staining belts and granules. Irregular less swollen deeply stained rods and small cocci (0.4 to 0.5 micron) which resemble the granules in the cystites are also present. These cocci are living cells. Non-motile. Gram-positive.

Gelatin colonies: Small, opaque, yellow. Liquefaction after 3 to 4 weeks.

Milk agar: Cystites develop in almost pure culture. These sometimes have 2 to 4 small cocci attached to the wall so that they look like budding yeasts. When transferred to fresh agar, cystites either fail to grow or germinate with 2 to 4 slender germ tubes which regenerate the rods. Cystites are produced most abundantly at 37°C, sometimes not at all at 16° to 18°C.

Sabouraud's agar: Cystites sometimes 6 to 8 microns in diameter. Growth may be cream-colored or even grayish-pink.

Asparagine agar: Growth thin, flat, moist, colorless.

Broth: Faint uniform turbidity; after 2 to 3 weeks, a soft white to cream-colored sediment.

Milk: Thin white ring around surface. Soft coagulation after 18 to 20 days. Later, slow digestion. Faintly acid.

Potato: Slow but eventually good growth, restricted, glistening, viscid, cream-colored to grayish-orange.

Acid from glucose, arabinose, galactose, maltose and glycerol; occasionally from sucrose and mannitol.

Nitrites produced from nitrates.

Optimum reaction pH 6.2 to 6.8.

Slimy variants produced after 172 days growth in lithium solution.

Source: Two strains from grass soils and one from garden soil in Australia.

Habitat: Soil.

24. **Corynebacterium simplex** Jensen. (Proc. Linn. Soc. New So. Wales, *59*, 1934, 43.) From Latin *simplex*, simple.

Rods: 0.4 to 0.5 by 3.0 to 5.0 microns, curved and in parallel bundles. No branching in older cultures but the cells grow shorter, becoming almost coccoid. Angular arrangement. Non-motile. Gram-positive.

Gelatin: Colonies very small. Filiform growth along stab. Liquefaction after 4 days.

Asparagine agar: Fair to good growth, becoming moist and glistening. No pigment.

Glucose agar: Abundant growth. Spreading, smooth, glistening, cream-colored to grayish-yellow.

Broth: Uniform turbidity, grayish-yellow, viscid sediment.

Milk: Yellowish ring around surface. No coagulation. Complete digestion after 10 to 12 days. Reaction neutral.

Nitrites produced from nitrates.

Starch is not hydrolyzed.

Acid from sucrose. Alkaline reaction in other sugar broths.

Excellent growth at 37°C.

Resembles *Corynebacterium filamentosum* in cultural characters but does not form long filaments.

Source: From grass soil and red soil from Griffith, Australia.

Habitat: Soil.

25. **Corynebacterium filamentosum** Jensen. (Proc. Linn. Soc. New So.

Wales, *59*, 1934, 42.) From Latin *filamentosus*, full of threads.

Rods: Variable in shape. Young cells typically curved, vibrio-like, 0.5 to 0.8 by 2.0 to 7.0 microns, sometimes longer and branched. Always in parallel bundles. Usually non-motile but a few cells exhibit a peculiar oscillatory or rotatory movement. Gram-positive.

Gelatin: Colonies small, spherical, entire. Filiform white growth in stab. Liquefaction slow starting at end of 7 days.

Asparagine agar: Good characteristic growth, widely spreading, central part convex, smooth, glistening, white, sending dendritic projections into the broad marginal part. Usually produces light greenish-yellow soluble pigment.

Glucose agar: Growth less vigorous than on asparagine agar, flat, cream-colored to grayish-yellow, viscid.

Sabouraud (whey) agar: Similar to glucose agar.

Potato: Scant to no growth, flat, glistening, cream-colored to grayish-yellow, surrounded by a white halo.

Broth: Faint uniform turbidity. Soft, flaky, cream-colored sediment.

Milk: White to cream-colored surface ring and sediment. No coagulation. Digestion in 2 to 4 weeks. Neutral to faintly acid.

May produce nitrites from nitrates.

Starch is not hydrolyzed.

Acid from glycerol and arabinose. Strong and rapid alkaline formation in other sugar media.

Optimum reaction pH 5.4 to 5.5.

Excellent growth at 37°C.

Aerobic.

Regarded as being much like *Vibrio lingualis* Eisenberg and *Bacterium racemosum* Zettnow.

Source: From red soil from Griffith, Australia.

Habitat: Soil.

Appendix I:* The following four species of plant pathogens have an unusual combination of characters in that they are reported to be Gram-positive and polar flagellate. Cultures of two of the four species have been available for study and these and other characters have been rechecked by several persons. *Corynebacterium flaccumfaciens* shows many wedge-shaped cells and longer cells with a slight curve. It is motile with a single polar flagellum and shows Gram-positive with commonly used procedures for Gram-staining. *Corynebacterium poinsettiae* shows a straighter form of cell but in other characters is like *C. flaccumfaciens*. Prof. W. H. Burkholder and Dr. M. P. Starr really feel that these organisms are most closely related to other more typical corynebacteria. They are therefore placed for the present in this appendix, although by the characters used in the keys they would be placed in *Pseudomonadaceae*.

1. **Corynebacterium hypertrophicans** (Stahel) *comb. nov.* (*Pseudomonas hypertrophicans* Stahel, Phyt. Ztschr., *6*, 1933, 445; *Phytomonas hypertrophicans* Magrou, in Hauduroy et al., Dict. d. Bact. Path., Paris, 1937, 367.) From Greek *hyper-trophe*, hypertrophy.

Rods: 0.6 to 0.8 by 1.2 to 2.8 microns. Motile with a polar flagellum. Bipolar staining. Gram-positive.

Gelatin: No growth.

Agar colonies: Slow growing, circular, raised, wet-shining, white.

Broth plus sucrose: Growth good. No pellicle.

Milk: No visible change.

Nitrites not produced from nitrates.

Indole not formed.

No H_2S produced.

Acid but no gas from glucose, fructose and sucrose. No acid from lactose and glycerol. The acids from sucrose are lactic and formic.

*Prepared by Prof. Walter H. Burkholder, New York State College of Agriculture, Ithaca, New York, May, 1945.

Aerobic.

Source: From witches' brooms.

Habitat: Pathogenic on *Eugenia latifolia*.

2. **Corynebacterium flaccumfaciens** (Hedges) Dowson. (*Bacterium flaccumfaciens* Hedges, Science, *55*, 1922, 433; Phytopath., *16*, 1926, 20; *Phytomonas flaccumfaciens* Bergey et al., Manual, 1st ed., 1923, 178; *Pseudomonas flaccumfaciens* Stevens, Plant Diseases of Fungi, 1925, 27; Dowson, Brit. Myc. Soc. Trans., *25*, 1942, 313.) From Latin *flaccus*, flabby or wilted; *facio*, to make; producing a wilt.

Rods: 0.3 to 0.5 by 0.6 to 3 microns. Motile with a single polar flagellum; also non-motile (Adams and Pugsley, Jour. Dept. Agr. Victoria., *32*, 1934, 306). Gram-positive.

Gelatin: Liquefaction feeble.

Beef agar slants: Rather moderate growth, glistening, flat, smooth, viscid and yellow.

Broth: Moderate turbidity in 24 hours. Pellicle formed.

Milk: Acid curd and slow peptonization.

Nitrites not produced from nitrates.

Indole not formed.

No H_2S formed.

Acid from glucose, lactose, sucrose and glycerol.

Starch not hydrolyzed.

Slight growth in 5 per cent salt.

Optimum temperature, 31°C. Maximum temperature 36° to 40°C.

Distinctive character: A strict vascular parasite of the bean.

Source: From wilted bean plants from South Dakota.

Habitat: Causes a wilt of beans and related plants.

3. **Corynebacterium poinsettiae** Starr and Pirone. (Phytopath., *32*, 1942, 1080; *Phytomonas poinsettiae*, *ibid.*) From M. L., old genus *Poinsettia*.

Rods: Average cells 0.3 to 0.8 by 1.0 to 3.0 microns. Pleomorphic with some cells 8.5 microns in length. Granules and capsules present. Motile with 1 (rarely 2) polar or lateral flagellum. Gram-positive.

Gelatin: Liquefaction.

Loeffler's blood-serum: Liquefaction.

Beef-extract agar colonies: Round, slightly convex, 0.1 to 1.0 mm in diameter, edges entire, smooth, non-viscid, colorless and almost transparent.

Potato glucose agar slants: Moderate growth, filiform, glistening, non-viscid, salmon to flesh color.

Beef-extract broth: Turbid in 24 hours, abundant pale salmon sediment. No pellicle.

Milk: Slight acidity but no other visible change for 2 weeks, then a soft curd, reduction of litmus, and complete peptonization.

Indole not produced.

Nitrites not produced from nitrates.

Hydrogen sulfide not formed.

Sodium hippurate not hydrolyzed.

Asparagine not utilized as carbon-nitrogen source. Uric acid not utilized; urea not hydrolyzed.

No lipolytic activity.

Voges-Proskauer test negative. Methyl red test negative.

Moderate to abundant acid, but no gas, from glucose, fructose, mannose, galactose, sucrose, maltose, cellobiose, melibiose, raffinose, glycerol, erythritol, salicin and amygdalin; weak acid from arabinose, xylose, lactose, trehalose, dextrin and adonitol; no acid from rhamnose, fucose, inulin, glycogen, mannitol, dulcitol, sorbitol and inositol.

Starch hydrolyzed.

No action on cellulose.

Tellurite reduced.

Aerobic.

Growth occurs after 24 hours from 15°C to 36°C; after 48 hours from 7°C to 12°C. No growth above 36°C or below 7°C at the end of a week.

Source: Fourteen cultures isolated from diseased stems of poinsettia, *Euphorbia pulcherrima*.

Habitat: Causes a canker of stems and spots on leaves of the poinsettia.

4. **Corynebacterium tritici** (Hutchinson) *comb. nov.* (*Pseudomonas tritici* Hutchinson, India Dept. of Agr., Bact. Ser., *1*, 1917, 174; *Phytomonas tritici* Bergey et al., Manual, 3rd ed., 1930, 248; *Bacterium tritici* Elliott, Bacterial Plant Pathogens, 1930, 234.) From Latin *triticum*, wheat; M. L., from the genus *Triticum*.

Rods: 0.8 by 2.4 to 3.2 microns. Motile with a polar flagellum. Gram-positive.

Gelatin: No liquefaction.

Agar colonies: Bright yellow becoming orange, glistening, moist, margins entire. Agar brownish.

Broth: Turbid. Thin pellicle.

Milk: Yellow surface and yellow precipitate. Little change.

Nitrites produced from nitrates.

No H_2S produced.

Acid but no gas from glucose and lactose.

This species is very similar to and may be identical with *Corynebacterium rathayi* Dowson.

Source: From slimy heads of wheat in India.

Habitat: Pathogenic on wheat, *Triticum aestivum*.

* **Appendix II**: By the use of names or by the descriptions given, authors have indicated that the following are related to the species placed in *Corynebacterium*. Many are incompletely described and may be identical with other recognized species.

Bacillus alcalifaciens Kurth. (*Bacillus pseudodiphtheriticus alcalifaciens* Kurth, Ztschr. f. Hyg., *28*, 1898, 429; *ibid.*, 431.) From patients suspected of having diphtheria.

Bacillus avium Migula. (Bacillus de la diphthérie aviaire, Loir and Ducloux, Ann. Inst. Past., *8*, 1894, 599; *Bacillus diphtheriae avium* Kruse, in Flügge, Die Mikroorganismen, 2 Aufl., *2*, 1896, 410; *Bacterium diphtheriae avium* (sic) Chester, Ann. Rept. Del. Col. Agr. Exp. Sta., *9*, 1897, 75; Migula, Syst. d. Bakt., *2*, 1900, 759.) Considered the cause of a diphtheria-like disease of birds in Tunis. Motile. Not now regarded as belonging in *Corynebacterium* (Andrewes et al., Diphtheria, London, 393).

Bacillus clavatus Kruse and Pasquale. (Kruse and Pasquale, Ztschr. f. Hyg., *16*, 1894, 50 and 62; not *Bacillus clavatus* Migula, Syst. d. Bakt., *2*, 1900, 597.) From the heart blood, kidney, etc., during autopsy of a person who died with liver abscesses following Egyptian dysentery. This is a pseudodiptheroid (Kruse, in Flügge, Die Mikroorganismen, 3 Aufl., *2*, 1896, 477) but is confused by Eberson (Jour. Inf. Dis., *23*, 1918, 5) and Thomson and Thomson (Ann. Pickett Thomson Res. Lab., *2*, 1926, 65) with anaerobic Bacillus No. III, a spore former isolated by Flügge (Ztschr. f. Hyg., *17*, 1894, 290) from boiled milk and named *Bacillus clavatus* by Migula (*loc. cit.*) in 1900.

Bacillus crassus Lipschütz. (Lipschütz, Bakt. Grundriss und Atlas der Geschlechtekrankheiten, Leipzig, 1913, 64; *Plocamobacterium crassum* Löwi, Wiener klin. Wchnschr., *33*, 1920, 733; not *Plocamobacterium vaginae* Lehmann, in Lehmann and Neumann, Bakt. Diag., 7 Aufl., *2*, 1927, 510.) This is the abundant Gram-positive bacillus found in ulcus vulvae acutum. It is the type species (monotypy) of the genus *Plocamobacterium* Löwi (*loc. cit.*). According to Löwi this organism liquefies coagulated blood serum and Lipschütz (Cent. f. Bakt., I Abt., Orig., *88*, 1922, 5) reports that, unlike lactobacilli, this organism will grow on protein media without the addition of sugar. Presumably therefore it is not a lactobacillus and is not identical with Doederlein's bacillus as claimed

* Prepared by Dr. R. F. Brooks, New York State Experiment Station, Geneva, New York, September, 1938; further revision by Prof. Robert S. Breed, New York State Experiment Station, Geneva, New York, March, 1945.

by Lehmann (*loc. cit.*) It may belong in *Corynebacterium*. See *Bacillus vaginae* Kruse.

Bacillus diphtheriae vitulorum Flügge. (Bacillus der diphtherie beim Kalbe, Löffler, Mitt. a. d. kais. Gesundheitsamte, *2*, 1884, 421; Flügge, Die Mikroorganismen, 2 Aufl., 1886, 265.) From a disease of calves.

Bacillus diphtheroides Klein. (Cent. f. Bakt., I Abt., *28*, 1900, 418.) From bovine mastitis. Presumably identical with *Corynebacterium pyogenes* according to Eberson (Jour. Inf. Dis., *23*, 1918, 6).

Bacillus endocarditis griseus Weichselbaum. (Weichselbaum, Beiträge z. path. Anat. u. allgem. Path., *4*, 1887, 119.) From a case of endocarditis. A motile form. Regarded by Kruse (in Flügge, Die Mikroorganismen, 3 Aufl., *2*, 1896, 433 and 479) as a diphtheroid. Because of its motility, it is not so regarded by Eberson (Jour. Inf. Dis., *23*, 1913, 4).

Bacillus pseudodiphtheriticus acidum aciens Kurth. (Ztschr. f. Hyg., *28*, 1898, 431.) From patients suspected of having diphtheria.

Bacillus pseudodiphtheriticus gazogenes Jacobsen. (Ann. Inst. Past., *22*, 1908, 308.) From feces. Reported to be a vigorous gas former. Eberson (Jour. Inf. Dis., *23*, 1918, 9) thinks this was an impure culture.

Bacillus septatus Gelpke. (Gelpke, in v. Graefe, Arch f. Opthal., *42*, 1896, No. 4; *Bacterium septatum* Gelpke, Arb. bakt. Inst. Karlsruhe, *2*, Heft 2, 1898, 73.) From acute epidemic catarrh. Presumably identical with *Corynebacterium xerose* according to Eberson (Jour. Inf. Dis., *23*, 1918, 3).

Bacillus variabilis lymphae vaccinalis Nakanishi. (Nakanishi, Cent. f. Bakt., I Abt., Orig., *27*, 1900, 641; *Corynethrix bovis* Czaplewski, Deutsche med. Wchnschr., *26*, 1900, 723.) From calf vaccine lymph. The organisms listed here as *Corynebacterium lymphae vaccinalis*, *Corynebacterium vaccinae* and *Bacillus variabilis lymphae vaccinalis* are probably identical.

Bacillus xerosis variolae Klein. (Rept. Local Gov. Board, London, *20*, 1890, 219, quoted from Thomson and Thomson, Ann. Pickett-Thomson Res. Lab., *2*, 1926, 121.) From vaccine pustules.

Bacterium acnes Migula. (Bacillus der Akne contagiosa des Pferdes, Dieckerhoff, Grawitz, Arch. f. pathol. Anat. u. Physiol., *102*, 1886, 148; *Bacillus grawitzii* Trevisan, I generi e le specie delle Batteriacee, 1889, 13; *Bacillus acnes-contagiosae* Kruse, in Flügge, Die Mikroorganismen, 3 Aufl., *2*, 1896, 445; Migula, Syst. d. Bakt., *2*, 1900, 385; *Bacterium grawitzii* Chester, Manual Determ. Bact., 1901, 154.) From pus and scabs of pustules in acne-contagiosa in horses.

Bacterium candidus Galli-Valerio. (Cent. f. Bakt., I Abt., Orig., *36*, 1904, 465.) From infected leg, but not considered causative.

Bacterium coelicolor Müller. (Müller, Cent. f. Bakt., I Abt., Orig., *46*, 1908, 195; *Bacillus coelicolor* Godfrin, Contribution à l'étude des bactéries bleues et violettes, Thèse, Nancy, 1934.) Contaminant on serum agar plate.

Bacterium columbarum Migula. (Bacillus der diphtherie bei der Taube, Löffler, Mitt. a. d. kais. Gesundheitsamte, *2*, 1884, 421; *Bacillus diphtheriae columbarum* Flügge, Die Mikroorganismen, 2 Aufl., 1886, 263; *Bacillus diphtheriae-columbarum* Trevisan, I generi e le specie delle Batteriacee, 1889, 13; *Bacterium diphtheriae columbarum* Chester, Ann. Rept. Del. Col. Agr. Exp. Sta., *9*, 1897, 84; Migula, Syst. d. Bakt., *2*, 1900, 381; not *Bacterium columbarum* Chester, Manual Determ. Bact., 1901, 141; *Bacterium diphtheriae* Chester, Man. Determ. Bact., 1901, 141; not *Bacterium diphtheriae* Migula, Syst. d. Bakt., *2*, 1900, 499.) Associated with diphtheria in pigeons. Andrewes et al. (Diphtheria, London, 1923, 393) state that this organism does not belong in *Corynebacterium*.

Bacterium muris Klein. (Cent. f.

Bakt., I Abt., Orig., *33*, 1902, 488; *Bacillus muris* Mellon, Jour. Bact., *2*, 1917, 305.) Causative agent of hepatized lung in white rat.

Bacterium pseudopestis murium Galli-Valerio. (Cent. f. Bakt., I Abt., Orig., *68*, 1913, 188.) Causative agent of thyroid infection in rats. Gram-negative.

Bacterium ribberti Migula. (Bacillus der Darmdiphtherie des Kaninchens, Ribbert, Deutsch. med. Wochnschr., *13*, 1887, 141; *Bacillus diphtheriae cuniculi* Kruse, in Flügge, Die Mikroorganismen, 3 Aufl., *2*, 1896, 412; *Bacterium diphtheriae cuniculi* Chester, Ann. Rept. Del. Col. Agr. Exp. Sta., *9*, 1897, 84; Migula, Syst. d. Bakt., *2*, 1900, 369; *Bacterium cuniculi* Chester, Man. Determ. Bact., 1901, 141.) Associated with a diphtheritic inflammation of the intestines in rabbits.

Coccobacillus diphtheroides Manteufel. (Diphtheroid bacilli, Collis, Sheldon and Hill, Quart. Jour. Med., Ser. 2, *1*, 1932, 511; *Kokkobacillus diphtheroides* Bertrand, Med. Welt, *8*, 1934, 150; Manteufel, Cent. f. Bakt., I Abt., Orig., *138*, 1937, 308.) From polyarthritis.

Comma variabile Heurlin. (Heurlin, Bakt. Unters. d. Keimgehaltes im Genitalkanale d. fiebernden Wöchnerinnen. Helsingfors, 1910, 145.) From genital canal.

Corynebacterium acidum Eberson. (*Bacillus diphtheroides brevis* Graham-Smith, Jour. Hyg., *4*, 1904, 258; Eberson, Jour. Inf. Dis., *23*, 1918, 9.) From large abscess in mouth and ear.

Corynebacterium adamsoni Prévot. (Bacillus D, Adamson, Jour. Path. and Bact., *22*, 1919, 350 and 392; Prévot, Ann. Inst. Past., *60*, 1938, 304.) From infected war wounds.

Corynebacterium album Belenky and Popova. (Cent. f. Bakt., I Abt., Orig., *118*, 1930, 444.) From normal skin of calves and small-pox vaccine.

Corynebacterium anaerobium Prévot. (*Bacillus anaerobius diphtheroides* Massini, Ztschr. f. gesammte exper. Med., *2*, 1913, 81; Prévot, Ann. Inst. Past., *60*, 1938, 304.) From a complicated case of otitis media.

Corynebacterium annamensis Hauduroy et al. (Gillon, Thèse pour le Doctorat Vetérinaire, École Nationale Vetérinaire de Toulouse, France, 1930; Hauduroy et al., Dict. d. Bact. Path., Paris, 1937, 145.) Causative agent of a toxic abdominal infection of sheep in Annam, French Indo-China.

Corynebacterium arthritidis muris Fischl, Koech and Kussat. (Ztschr. f. Hyg., *112*, 1931, 421; *Corynebacterium arthritidis-muris* Hauduroy et al., Dict. d. Bact. Path., 1937, 147.) Causative agent of infected ankle joint in white mouse.

Corynebacterium ascitis Eberson. (Jour. Inf. Dis., *23*, 1918, 16.) From ascitic fluid.

Corynebacterium aurantiacum Eberson. (Jour. Inf. Dis., *23*, 1918, 14.) Orange-red growth. From lymph nodes; one culture from gland in Hodgkin's disease but not specific for the disease.

Corynebacterium auris (Graham-Smith) Eberson. (*Bacillus auris* Graham-Smith, Jour. Hyg., *4*, 1904, 258; Eberson, Jour. Inf. Dis., *23*, 1918, 8.) Indole is formed. From pus of ears of scarlet fever patients.

Corynebacterium avidum (Eggerth) Prévot. (*Bacteroides avidus* Eggerth, Jour. Bact., *30*, 1935, 289; Prévot, Ann. Inst. Past., *60*, 1938, 304.) Forms gas in some media. From the human intestine. Pederson (Jour. Bact., *50*, 1945, 478) secured a culture of this species from Eggerth, and found that it fermented glucose with the production of higher fatty (presumably butyric) acids, and lactic acid. The species should probably be placed in *Butyribacterium* Barker.

Corynebacterium blattellae Glaser. (Jour. Exp. Med., *51*, 1930, 907.) Found in the fat body of the German cockroach (*Blattella germanica*). For a more complete description see Manual, 5th ed., 1939, 978.

Corynebacterium bruneum Kisskalt and Berend. (*Bacterium bruneum γ arborescens*, quoted from Kisskalt and Berend, Cent. f. Bakt., I Abt., Orig., *81*, 1918, 446; Kisskalt and Berend, *idem.*) Source not given.

Corynebacterium cerebralis Eberson. (Jour. Inf. Dis., *23*, 1918, 17.) From the brain in a case of meningitis.

Corynebacterium ceruminis (Graham-Smith) Eberson. (*Bacillus ceruminis* Graham-Smith, Jour. Hyg., *4*, 1904, 258; Eberson, Jour. Inf. Dis., *23*, 1918, 8.) Indole is not formed. From normal and scarlet fever-infected ears.

Corynebacterium commune Martin. (Compt. rend. Soc. Biol., Paris, *81*, 1918, 991 and 998.) From the pharynx.

Corynebacterium cremoides (Lehmann and Neumann) Jensen. (*Bacterium cremoides* Lehmann and Neumann, Bakt. Diag., 1 Aufl., *2*, 1896, 253; Jensen, Proc. Linn. Soc. New So. Wales, *59*, 1934, 40.) From tapwater, Würzburg. Lehmann and Neumann recognize this species as a *Corynebacterium* in the seventh edition of their determinative bacteriology (Bakt. Diag., 7 Aufl., *2*, 1927, 710) but do not use the binomial *Corynebacterium cremoides* except in the index, page 848. Jensen has reisolated this organism from soil in Australia. *Bacterium cocciforme* Migula (Kultur No. 2, Severin, Cent. f. Bakt., II Abt., *1*, 1895, 160; Migula, Syst. d. Bakt., *2*, 1900, 439) from manure is regarded by Jensen (*loc. cit.*) as closely related to this species.

Corynebacterium cuculi (Graham-Smith) Bergey et al. (*Bacillus cuculi* Graham-Smith, Jour. of Hyg., *4*, 1904, 315; Bergey et al., Manual, 1st ed., 1923, 387.) From the throat of a cuckoo. For a more complete description see Manual, 5th ed., 1939, 802.

Corynebacterium cuniculi Hauduroy et al. (*Bacillus pyogenes cuniculi* Cominotti, Clinica Veterinaria, *44*, 1921, 45; Hauduroy et al., Dict. d. Bact. Path., 1937, 147). Reported as Gram-variable by Cominotti, as Gram-negative by Hauduroy et al. Causative agent of suppurative infection of rabbit.

Corynebacterium cutis Hauduroy et al. (*Bacillus cutis communis* Nicolle, quoted from Costa, Troisser and Dauvaugne, Compt. rend. Soc. Biol., Paris, *81*, 1918, 1003; *Bacillus cutis* Costa, Troisser and Dauvaugne, *ibid.*, 1004; *Bacterium cutis commune* Nicolle, quoted from Debré and Letulle, La Presse Méd., *27*, 1919, 515; Hauduroy et al., Dict. d. Bact. Path., 1937, 148). From normal skin and nasal passages.

Corynebacterium delicatum Eberson. (Jour. Inf. Dis., *23*, 1918, 16.) From ascitic fluid. Also from blood.

Corynebacterium dermophilum (Rohde) Andrewes et al. (*Bacillus dermophilus* Rohde, Münch. med. Wchnschr., *68*, 1921, 234; Andrewes, Bulloch, Douglas, Dreyer, Fildes, Ledingham and Wolf, Diphtheria, London, H. M. Stationery Office, 1923, 391.) From the skin.

Corynebacterium diphtheroides Prévot. (Bacille diphtheroide, Jungano, Compt. rend. Soc. Biol., Paris, *61*, 1909, 112; Prévot, Ann. Inst. Past., *60*, 1938, 304.) Forms gas in some media. From the intestines of white rats.

Corynebacterium epidermidis Eberson. (Jour. Inf. Dis., *23*, 1918, 17.) From skin and pus pockets. Resembles *Corynebacterium suppuratum* Eberson.

Corynebacterium flocculens Eberson. (Jour. Inf. Dis., *23*, 1918, 17.) From a case of appendicitis.

Corynebacterium gallinarum Bergey et al. (*Bacillus diphtheroides gallinarum* Graham-Smith, Jour. of Hyg., *4*, 1904, 314; Bergey et al., Manual, 1st ed., 1923, 387.) From the throats of chickens. For a more complete description see Manual, 5th ed., 1939, 802.

Corynebacterium glandulae Eberson. (Jour. Inf. Dis., *23*, 1918, 14.) From lymph glands in Hodgkin's disease but not specific for the disease.

Corynebacterium granulomatis maligni de Negri and Mieremet. (Cent. f. Bakt., I Abt., Orig., *68*, 1913, 292.) Causative agent of human malignant granuloma.

Corynebacterium granulosum Prévot. (Bacille granuleux, Jungano, Compt. rend. Soc. Biol., Paris, *66*, 1909, 123; Prévot, Ann. Inst. Past., *60*, 1938, 304.) From the intestines of white rats.

Corynebacterium hepatodystrophicans (Kuczinski) Prévot. (*Bacillus hepatodystrophicans* Kuczinski, Der Erreger des Gelbfiebers-Wesen und Wirkung, Monographie, 1929, Berlin; Prévot, Ann. Inst. Past., *60*, 1938, 304.) Manteufel (Cent. f. Bakt., I Abt., Orig., *138*, 1937, 309) regards this species as identical with *Bacillus renale* (*cuniculi*) Manteufel and Herzberg. Common in the organs of monkeys infected with yellow fever virus.

Corynebacterium hodgkinii Bunting and Yates. (Bunting and Yates, Arch. Internal Med., *12*, 1913, 236; Johns Hopkins Hosp. Bull., *25*, 1914, 173; *Bacillus hodgkini* Mellon, Jour. Bact., *2*, 1917, 271; *Fusiformis hodgkini* Holland, Jour. Bact., *5*, 1920, 223.) From lymph glands in Hodgkin's disease. Not pathogenic. Thought by Fox (Jour. Med. Res., *32*, 1915, 309) and Eberson (Jour. Inf. Dis., *23*, 1918, 11) not to represent a definite species. Eberson recognized four separate species isolated from human lymph glands, three being from glands in Hodgkin's disease (*Corynebacterium aurantiacum*, *C. pseudodiphtheriae*, *C. glandulae* and *C. lymphophilum*).

Corynebacterium liquefaciens Prévot. (*Bacillus parvus liquefaciens* Jungano, Compt. rend. Soc. Biol., Paris, *65*, 1908, 618; Prévot, Ann. Inst. Past., *60*, 1938, 304; not *Corynebacterium liquefaciens* Andrewes et al., Diphtheria, London, 1923, 408; not *Corynebacterium liquefaciens* Jensen, Proc. Linn. Soc. New So. Wales, *59*, 1934, 49.) From human intestine.

Corynebacterium liquefaciens Andrewes et al. (*Bacillus diphtheroides liquefaciens* Graham-Smith, Jour. Hyg., *4*, 1904, 258; *Bacillus liquefaciens* Mellon, Jour. Bact., *2*, 1917, 290; Andrewes, Bulloch, Douglas, Dreyer, Fildes, Ledingham, and Wolf, Diphtheria, London, 1923, 408.) From mouth of a patient. Motile.

Corynebacterium lymphae vaccinalis Levy and Fickler. (Deutsch. med. Wchnschr., *26*, 1900, 418; *Corynebacterium pyogenes* Lewandowsky, Cent. f. Bakt., I Abt., Orig., *36*, 1904, 473.) From animal lymph.

Corynebacterium lymphophilum (Torrey) Eberson. (*Bacillus lymphophilus* Torrey, Jour. Med. Res., *34*, 1916, 79; Eberson, Jour. Inf. Dis., *23*, 1918, 23.) Anaerobic. From lymph glands in Hodgkin's disease, but not specific for the disease.

Corynebacterium maculatum (Graham-Smith) Ford. (*Bacillus maculatus* Graham-Smith, Jour. Hyg., *4*, 1904, 258; Ford, Textb. Bact., 1927, 277.) From throat. Regarded as a *Corynebacterium* by Eberson (Jour. Inf. Dis., *23*, 1918, 7).

Corynebacterium metritis Hauduroy et al. (Souckin, Sovetskaia Veter., No. 11, 1934; Hauduroy et al., Dict. d. Bact. Path., 1937, 156.) Causative agent of metritis in rabbit.

Corynebacterium miltinum Kisskalt. (Quoted from Kisskalt and Berend, Cent. f. Bakt., I Abt., Orig., *81*, 1918, 446). Source not given.

Corynebacterium nodosum (Migula) Eberson. (*Bacillus nodosus parvus* Lustgarten-Mannaberg, Vierteljahrschrift f. Dermatol. u. Syphilis, 1887, 914; *Bacterium nodosum* Migula, Syst. d. Bakt., *2*, 1900, 416; Eberson, Jour. Inf. Dis., *23*, 1918, 4.) Found in the normal human urethra.

Corynebacterium nubilum (Frankland and Frankland) Jensen. (*Bacillus nubilus* Frankland and Frankland, Ztschr. f. Hyg., *6*, 1889, 386; *Bacterium nubilum* Lehmann and Neumann, Bakt. Diag., 1 Aufl., *2*, 1896, 255; *Chromobacterium nubile* Ford, Textb. of Bact., 1927, 472; *Flavobacterium nubilum*, incorrectly ascribed to Bergey, by Jensen, Proc. Linn. Soc. New So. Wales, *59*, 1934, 44; Jensen, *idem*.) From water and soil. The identity of this species is doubtful. The original description by the Franklands is incomplete. Zimmerman (Bakt. unserer Trink- u. Nutzwässer, Chemnitz, *1*,

1890, 28) thought he found the same organism and described it as Gram-negative. Lehmann and Neumann (Bakt. Diag., 1 Aufl., *2*, 1896, 255) who studied one of Zimmermann's cultures reported this culture as Gram-positive and non-motile, while the Franklands and Zimmermann speak of an active, circular motility of the very slender rods. Lehmann and Neumann later (Bakt. Diag., 7 Aufl., *2*, 1927, 710) list their *Bacterium nubilum* (with other Gram-positive, non-motile rods) as a possible *Corynebacterium*. Jensen failed to find anything that exactly corresponded to any of these descriptions but describes a small, Gram-positive, poorly-growing, pink to red, slow gelatin-liquefying rod which he says has little in common with corynebacteria as a new variety *Corynebacterium nubilum* var. *nanum*. Because the early cultures developed rhizoid growths in stiff gelatin before liquefaction, Zimmermann originally planned to call this species *Bacillus nebulosus* (*loc. cit.*, 29), a name that has been used by later authors for several different organisms. Attention should be called also to *Bacillus caudatus* Wright, an organism which Conn found to show occasional motility (polar) and named *Pseudomonas caudatus*. This common, slender, gelatin-liquefying, Gram-negative, white to yellow chromogenic rod is much like the Franklands' and Zimmermann's organism (see Conn, New York State Exp. Sta. Tech. Bull. 67, 1919, 38).

Corynebacterium paralyticans (Robertson) Ford. (*Bacillus paralyticans* Robertson, Rev. Neurol. and Psychiat., Edinburgh, *1*, 1903, 470; Ford, Textb. of Bact., 1927, 281.) From cerebrospinal fluid. A diphtheroid. Thought at one time to be the causal agent of general paralysis.

Corynebacterium parvum Prévot. (*Corynebacterium parvum infectiosum* Mayer, Cent. f. Bakt., I Abt., Orig., *98*, 1926, 370; Prévot, Man. de Class. et Déterm. des Bactéries Anaérobies, Monographie, Inst. Past., Paris, 1940, 202.) From blood in a post-natal fever.

Corynebacterium periplanetae Bergey et al. (*Corynebacterium periplanetae* var. *americana* Glaser, Jour. Exp. Med., *51*, 1930, 59; Bergey et al., Manual, 4th ed., 1934, 550.) Found in the fat body of the American cockroach (*Periplaneta americana*). For a more complete description see Manual, 5th ed., 1939, 798.

Corynebacterium plumosum (Fox) Ford. (*Mycobacterium plumosum* Fox, Cent. f. Bakt., I Abt., Orig., *70*, 1913, 148; Ford, Textb. Bact., 1927, 281.) From blood of patient with chronic endocarditis.

Corynebacterium pseudodiphtheriae Eberson. (Jour. Inf. Dis., *23*, 1918, 14.) Hemoglobinophilic. From tonsils.

Corynebacterium putidum Eberson. (*Bacillus diphtheroides liquefaciens* Graham-Smith, Jour. Hyg., *4*, 1904, 258; Eberson, Jour. Inf. Dis., *23*, 1918, 16.) From mouth. Cultures described by Graham-Smith liquefied gelatin and were sluggishly motile.

Corynebacterium pyogenes bovis (Roux) Prévot. (*Bacillus pyogenes bovis* Roux, Cent. f. Bakt., I Abt., Orig., *34*, 1905, 541; *Eubacterium pyogenes bovis* Prévot, Ann. Inst. Past., *60*, 1938, 295; Prévot, Man. de Class. et Déterm. des Bactéries Anaérobies, Monographie, Inst. Past., Paris, 1940, 204.) Common in bovine suppurations. Said by Roux to be identical with *Bacillus pyogenes bovis* Kunnemann. Prévot says it is probably identical with the pyogenic *Corynebacterium* of Lucet. See *Corynebacterium pyogenes* Eberson.

Corynebacterium renale cuniculi Prévot. (*Bacterium renale* and *Bacterium renale* (*cuniculi*) Manteufel and Herzberg, Cent. f. Bakt., I Abt., Orig., *116*, 1930, 266; *Bacillus renale* and *Bacillus renale* (*cuniculi*) Manteufel, *ibid.*, *138*, 1937, 306; Prévot, Ann. Inst. Past., *60*, 1938, 304.) Gram-variable. Forms gas in some media. From rabbit kidneys.

Corynebacterium ruedigeri (Mellon)

Ford. (Virulent pseudodiphtheria bacillus, Hamilton, Jour. Inf. Dis., *1*, 1904, 711; Ruediger's bacillus, Mellon, Jour. Bact., *2*, 1917, 285; *Bacillus ruedigeri* Mellon, *ibid.*, 290; Ford, Textb. Bact., 1927, 274.) From throats of fatal cases of scarlatina.

Corynebacterium segmentosum Eberson. (*Bacillus coryzae segmentosus* Cautley, Rept. Med. Officer of Health, Local Govt. Board, London, 1894–95, 455; *Bacillus septus* Benham, Brit. Med. Jour., *1*, 1906, 1023; Eberson, Jour. Inf. Dis., *23*, 1918, 17; *Bacillus segmentosus* Holland, Jour. Bact., *5*, 1920, 220.) Rods of variable dimensions, mostly resembling *Corynebacterium pseudodiphtheriticum* Lehmann and Neumann, but occasionally resembling *Corynebacterium diphtheriae* Lehmann and Neumann. Thomson and Thomson (Ann. Pickett-Thomson Res. Lab., *2*, 1926, 65) do not think Cautley's bacillus is recognizable. From nasal secretions.

Corynebacterium squamosum Belenky and Popova. (Cent. f. Bakt., I Abt., Orig., *118*, 1930, 444.) From normal skin of calves and small-pox vaccine. Nonhemolytic.

Corynebacterium striatum (Chester) Eberson. (*Bacillus striatus flavus* and *Bacillus striatus albus* von Besser, Beitr. z. path. Anat. u. Path., *6*, 1888, 349; *Bacterium striatus flavus* Chester, Ann. Rept. Del. Col. Agr. Exp. Sta., *9*, 1897, 111; *Bacterium striatum* Chester, Man. Determ. Bact., 1901, 171; *Bacillus flavidus* Morse, Jour. Inf. Dis., *11*, 1912, 281; *Corynebacterium flavidum* Holland, Jour. Bact., *5*, 1920, 218; Eberson, Jour. Inf. Dis., *23*, 1918, 5.) Eberson (*loc. cit.*, 7) states that *Bacillus diphtheroides citreus* Graham-Smith (Jour. Hyg., *4*, 1904, 258) corresponds with the yellow variety of this species. From nasal mucus. Resembles *Corynebacterium segmentosum*.

Corynebacterium suis Hauduroy et al. (Le bacille pyogenes suis, Colin and Rossi, Revue gén. de Méd. vetér., *40*, 1931, 137; Hauduroy et al., Dict. d. Bact. Path., 1937, 167). Causative agent of caseous suppuration of swine. Gram-negative.

Corynebacterium suppuratum Eberson. (Jour. Inf. Dis., *23*, 1918, 17.) From anal pus pocket. Resembles *Corynebacterium epidermidis* Eberson.

Corynebacterium thermophilus Zavagli. (Amer. Jour. Hyg., *15*, 1932, 504.) From raw and pasteurized milk. Grows better at 55°C than at 37°C.

Corynebacterium typhi Topley and Wilson. (*Bacillus typhiexanthematici* Plotz, Jour. Amer. Med. Assoc., *62*, 1913, 1556; La Presse Méd., *43*, 1914, 411; Plotz, Olitsky and Baehr, Jour. Inf. Dis., *17*, 1915, 17; not *Bacillus typhi exanthematici* Klebs, Proc. Internat. Med. Cong., *1*, 1881, 323; *Corynebacterium typhi-exanthematici* Eberson, Jour. Inf. Dis., *23*, 1918, 19; *Bacterium typhi-exanthematici* Holland, Jour. Bact., *5*, 1920, 222; *Fusiformis typhi-exanthematici* Holland, *ibid.*, 221; Topley and Wilson, Prin. of Bact. and Immun., 2nd ed., 1936, 349; *Eubacterium typhi-exanthematici* Prévot, Ann. Inst. Past., *60*, 1938, 295.) From blood of typhus fever patients.

Corynebacterium ulcerogenes Bergey et al. (*Corynebacterium diphtheriae ulcerogenes cutaneum* Mrongovius, Cent. f. Bakt., I Abt., Orig., *112*, 1929, 51; Bergey et al., Manual, 4th ed., 1934, 550.) From ulcerations of the skin (human). Resembles *Corynebacterium epidermidis* Eberson and *C. suppuratum* Eberson.

Corynebacterium vaccinae Galli-Valerio. (Cent. f. Bakt., I Abt., Orig., *36*, 1904, 465.) From vaccine pustules in calves.

Corynebacterium xerosis canis (Graham-Smith) Ford. (*Bacillus xerosis canis* Graham-Smith, Jour. Hyg., *4*, 1904, 258; Ford, Textb. Bact., 1927, 271.) From conjunctival sacs of dogs.

Corynethrix hominis, *C. equi*, *C. canis*, *C. anatis*, etc. Czaplewski. (Deutsche med. Wchnschr., *26*, 1900, 723.) Hypothetical species from the skin of the animals indicated.

Corynethrix pseudotuberculosis murium Bongert. (Ztschr. f. Hyg., *37*, 1901,

472.) From a multiple, necrotic, caseous pneumonia of mice inoculated with material from equine pneumonia. Regarded by the author as distinct from *Bacillus pseudotuberculosis murium* Kütscher. Placed in the genus *Corynethrix* Czaplewski (Deutsche med. Wchnschr., *26*, 1900, 723).

Lactobacillus meleagridis Johnson and Pollard. (Diplo-bacillus P_1, Johnson and Anderson, Jour. Inf. Dis., *58*, 1936, 340; Johnson and Pollard, Jour. Inf. Dis., *66*, 1940, 196.) From heart, liver and yolk of moribund turkey poults. Presumably a *Corynebacterium*, not a true *Lactobacillus*.

Einer sporogenen Pseudo-Diphtheriebazillus, De Simoni. (Cent. f. Bakt., I Abt., Orig., *24*, 1898, 294.) From nasal secretion in ozena. Produced spores only in milk and on potato. Thought by Eberson (Jour. Inf. Dis., *23*, 1918, 6) to have been a contaminated culture.

Organism in M. H., De Witt. (Jour. Inf. Dis., *10*, 1912, 40.) A motile, gas-producing diphtheroid isolated from a generalized diphtheria-like infection.

Appendix III:* The relationships of the following soil organism are not clear, but it apparently should be placed either in *Corynebacterium* or in a related genus (e.g., *Mycobacterium*). On agar it is rod-shaped and generally Gram-negative in young cultures, but coccoid and Gram-positive in old cultures, a condition noted by Mellon (Jour. Bact., *2*, 1917, 278) in connection with *Corynebacterium enzymicum*. Something similar is noted by Jensen (Proc. Linn. Soc. New So. Wales, *59*, 1934, 29–62) in his description of *Corynebacterium helvolum*. Krassilnikov, on the other hand (Cent. f. Bakt., II Abt., *90*, 1934, 432), suggests that this species really belongs to *Mycobacterium*, and, after seeing a culture furnished him by Conn, has become all the more convinced of this relationship (personal correspondence).

Krassilnikov's studies indicate that there is a group of soil bacteria that grow as rods in young cultures with a tendency to produce branching forms in liquid media and develop coccoid bodies as they grow older. The latter then even divide and multiply like cocci. He considers that practically all so-called micrococci found among soil cultures are really the older stages of *Mycobacterium spp.* It is very clear that Jensen and Krassilnikov, the two leading students of the saprophytic members of this group found in soil, do not agree as to what constitutes the genus *Mycobacterium*; their papers appeared almost simultaneously and clearly represent independent work. Krassilnikov's description of this genus comes closest to covering organisms like the following of any of the descriptions in the literature, but it is quite different from Jensen's idea of the genus. In fact, the descriptions given by the former author seem to be more like Jensen's conception of the genus *Corynebacterium*. Jensen, in his description, takes into account the relative acid-fast staining properties of the groups; but Krassilnikov does not mention either this property or the Gram stain. Inasmuch as the acid-fast property is regarded in the present classification as an important characteristic of *Mycobacterium*, the following species is included as an appendix, not of that genus, but of *Corynebacterium*. The relationships of these pleomorphic soil organisms must be regarded as decidedly obscure. Lochhead (Can. Jour. Res., Sec. C, *16*, 1938, 156) speaks of a *Bacterium globiforme* group and Conn (Jour. Bact., *48*, 1945, 359) has recently reported evidence in support of Lochhead's viewpoint. In all probability this group is identical in whole or in part with Krassilnikov's *Mycobacterium* of soil, although the correctness of his choice of this generic name may be questioned.

***Prepared by Prof. H. J. Conn, New York State Experiment Station, Geneva, New York, July, 1945.**

Bacterium globiforme Conn. (Conn, N. Y. Agr. Exp. Sta. Tech. Bull. 138, 1928 and 172, 1930; Cent. f. Bakt., II Abt., *76*, 1928, 77; *Achromobacter globiforme* Bergey et al., Manual, 3rd ed., 1930, 226.) From Latin, having the form of a globe or sphere.

Short rods: 0.4 to 0.6 by 0.6 to 0.8 micron, becoming coccoid in older cultures. In certain liquid synthetic media, branching forms with Gram-positive spherical granules are common. These granules have a tendency to be acid-fast. Non-motile. Rods usually Gram-negative; coccoid forms usually Gram-positive.

Gelatin colonies: Circular, punctiform.

Gelatin stab: Slow crateriform liquefaction.

Agar colonies: Circular, punctiform, translucent.

Agar slant: Filiform, flat, smooth, soft, translucent, glistening growth with translucent sheen.

Broth: Slight growth.

Nitrites produced from nitrates in synthetic agar media.

Glucose, sucrose, mannitol, and less readily lactose and various organic acids are utilized as sources of carbon and energy when grown in synthetic media. No visible gas production, and probably no acid except carbonic acid.

Nitrogen may be obtained from ammonium sulfate, asparagine, cystine, glycerol, aspartic acid, uric acid, tyrosin, potassium nitrate, urea and peptone.

Aerobic, facultative.

Optimum temperature 22°C.

Source: Seventy cultures isolated from soil.

Habitat: Widely distributed in soil.

Genus II. Listeria *Pirie.**

(*Listerella* Pirie, Publ. So. African Inst. for Med. Res., *3*, 1927, 163; not *Listerella* Jahn, Ber. d. deutsch. Bot. Ges., *24*, 1906, 538; not *Listerella* Cushman, Contr. Cushman Lab. Foram., Sharon, Mass., *9*, 1933, 32; Pirie, Science, *91*, 1940, 383.) Named for Joseph Lister, the English surgeon and bacteriologist.

Small rods, Gram-positive. Flagellation peritrichous. Aerobic. Catalase positive. Grow freely on ordinary media. Acid but no gas from glucose and a few additional carbohydrates. Pathogenic parasites. Infection characterized by a monocytosis. Parasitic on warm-blooded animals.

The type species is *Listeria monocytogenes* (Murray et al.) Pirie.

1. **Listeria monocytogenes** (Murray et al.) Pirie. (*Bacterium monocytogenes* Murray, Webb and Swann, Jour. Path. and Bact., *29*, 1926, 407; *Listerella hepatolytica* Pirie, Publ. S. African Inst. for Med. Res., *3*, 1927, 164; *Listerella monocytogenes* Pirie, *ibid.; Listerella monocytogenes hominis* Nyfeldt, Folia Haematologica, *47*, 1932; *Corynebacterium parvulum* Schultz, Terry, Brice and Gebhardt, Proc. Soc. Exp. Biol. Med., *31*, 1934, 1021; Pirie, Science, *91*, 1940, 383; *Bacillus monocytogenes* Tobia, Arch. ital. med. colon., *23*, 1942, 219; abst. in Cent. f. Bakt., I Abt., Ref., *144*, 1943, 199.) Derived from the Greek, meaning generating monocytes.

Small rods: 0.4 to 0.5 by 0.5 to 2.0 microns, with rounded ends, slightly curved in some culture media. Occur singly, in V-shaped or parallel pairs and in short chains. Motile, peritrichous (Paterson, Jour. Path. and Bact., *48*, 1939, 25) with four flagella at ordinary temperatures with tendency toward non-motility or single flagellum at 37°C (Griffin, Jour. Bact., *48*, 1944, 114). Not acid-fast. Gram-positive.

Gelatin: No liquefaction. Growth is confined to the needle track.

In 0.25 per cent agar, 8.0 per cent gelatin, 1.0 per cent glucose semisolid medium, growth along the stab in 24 hours at 37°C, followed by irregular cloudy or

* Revised by Prof. E. G. D. Murray, McGill Univ., Montreal, P. Q., Canada, September, 1938; further revision, January, 1945.

granular extensions into the medium; growth does not spread through the entire medium. This is characteristic (Seastone, Jour. Exp. Med., *62*, 1935, 203).

Sheep liver extract agar colonies: Circular, smooth, slightly flattened, transparent by transmitted and milk-white by reflected light. Viscid.

Sheep liver extract agar slant: Confluent, flat, transparent, viscid growth.

Peptone agar: Growth is thinner than on liver extract agar.

Blood agar: Improved growth with zone of hemolysis around colonies.

Peptone broth: Surface film with flocculent sediment.

Litmus milk: Slightly acid, decolorized. No coagulation.

Glycerol-potato: No apparent growth.

Inspissated ox serum: Grows as a very thin, transparent film.

Dorset's egg medium: Very thin film.

Indole not formed.

Hydrogen sulfide not formed.

Nitrites not produced from nitrates.

Acid but no gas from glucose, rhamnose and salicin promptly, more slowly from dextrin, sucrose, soluble starch and glycerol. Acid production may be variable and slow from maltose and lactose. No action on arabinose, galactose, xylose, mannitol, dulcitol, inulin and inositol.

All cultures give off a penetrating, rather unpleasant acid smell.

Aerobic, facultative.

Optimum temperature 37°C. Thermal death point 58° to 59°C in 10 minutes.

Animal inoculations: Injection of rabbits with cultures results in a very marked increase in monocytes circulating in the blood. This is the most striking character of the organism and is exhibited by strains derived from all sources. Infection is characterized by necrotic foci in various organs.

Serological characters: Agglutination and absorption of agglutinin reactions show a variation in degree with different strains but there is no definite indication that strains from different kinds of animal hosts are different species. Paterson (Jour. Path. and Bact., *57*, 1940, 427) concludes from his studies of the flagellar and somatic antigens of 54 cultures that four types may be recognized in this species. These do not bear any relation to the host species or to the geographical area from which they were isolated.

Possibly related to *Erysipelothrix* (Barber, Jour. Path. and Bact., *48*, 1939, 11).

Habitat and source: Lesions in organs, blood, cerebrospinal fluid of rabbits, guinea pigs, sheep, cattle, foxes, hogs, fowls, gerbilles and man, in all of which natural disease occurs. Many cases have proved fatal. The cause of infectious mononucleosis in man (Nyfeldt, *loc. cit.*).

Appendix: The following binomials have also been proposed for species in this genus.

Bacterium hepatis Hülphers. (Sven. Vet.-Tidskrift, *2*, 1911, 271.) From necrosis of the liver of a rabbit. Nyfeldt (Skand. Vet.-Tidskrift, *30*, 1940, 284) regards this as a synonym of *Listerella monocytogenes*. However, failure to ferment lactose, rhamnose, sucrose and salicin with fermentation of xylose, and failure to infect guinea pigs and chickens indicate a possible difference between the two species.

Listerella hibiscus liquefaciens Nakahama. (Jour. Agr. Chem. Soc. Japan, *16*, 1940, 345.) From retted kenaf (*Hibiscus*).

Listerella hominis, *Listerella bovina*, *Listerella gallinarum*, *Listerella cunicula* and *Listerella gerbilli* Wramby. (Skand. Vet.-Tidskrift, *34*, 1944, 280.) These names are given to indicate cultures of *Listerella monocytogenes* from man, cattle, chickens, rabbits and gerbilles, respectively.

Listerella ovis Gill. (Australian Vet. Jour., *13*, 1937, 47.) Causes circling disease of sheep.

Burn (Jour. Bact., *30*, 1935, 573) reports, but does not name, a new species in this genus.

Genus III. **Erysipelothrix** *Rosenbach.**

(Ztschr. f. Hyg., *63*, 1909, 367.) From Greek *erysipelas*, a disease; and *thrix*, hair or thread.

Rod-shaped organisms with a tendency to the formation of long filaments. The filaments may also thicken and show characteristic granules. Non-motile. Gram-positive. Microaerophilic. Catalase negative. Grow freely on ordinary media. Acid but no gas from glucose and a few additional carbohydrates. Parasitic on mammals.

The type species is *Erysipelothrix rhusiopathiae* (Migula) Winslow et al.

1. **Erysipelothrix rhusiopathiae** (Migula) Winslow et al. (Bacillus des Schweinerotlaufs, Loeffler, Arb. a. d. k. Gesundheitsamte, 1, 1886, 46; *Bacillus thuillieri* Trevisan, I generi e le specie delle Batteriacee, 1889, 13; *Pasteurella thuillieri* DeToni and Trevisan, in Saccardo, Sylloge Fungorum, *8*, 1889, 995; *Bacillus rhusiopathiae suis* Kitt, Bakterienkunde u. path. Mikroscopie, 1893, 284; *Bacterium erysipelatos suum* (sic) Migula, in Engler and Prantl, Die natürl. Pflanzenfam., *1*, 1a, 1895, 24; *Bacterium rhusiopathiae suis* Chester, Ann. Rept. Del. Col. Agr. Exp. Sta., *9*, 1897, 98; *Bacterium rhusiopathiae* Migula, Syst. d. Bakt., *2*, 1900, 43; *Mycobacterium rhusiopathiae* Chester, Man. Determ. Bact., 1901, 352; *Erysipelothrix porci* Rosenbach, Ztschr. f. Hyg., *63*, 1909, 367; Winslow et al., Jour. Bact., *5*, 1920, 198; *Bacillus erysipelatos-suis* Holland, Jour. Bact., *5*, 1920, 218; *Erysipelothrix erysipelatos-suis* Holland, *ibid. Bacillus ruboris suis* Neveu-Lemaire, Précis Parasitol. Hum., 5th ed., 1921, 24; *Nocardia thuillieri* Vuillemin, Encyclopédie Mycologique, Paris, *2*, 1931, 125; *Actinomyces thuillieri* Nannizzi, in Pollacci, Tratt. Micopat. Umana, *4*, 1934, 45.) From Greek *rhusius*, reddish; *pathus*, a disease; red disease.

Description taken in part from Karlson, Jour. Bact., *35*, 1938, 205.

Slender rods: 0.2 to 0.3 by 0.5 to 1.5 microns, occurring singly and in chains. Non-motile. Gram-positive.

Gelatin colonies: Hazy, bluish-gray, racemose; situated a little below the surface, growing slowly.

Gelatin stab: Small, fimbriate colonies in the stab, at times definitely arborescent. No surface growth. No liquefaction.

Agar slant: Scant growth, translucent, moist, homogeneous.

Broth: Slight turbidity, with scant, grayish sediment.

Litmus milk: May become slightly acid.

Indole not formed.

Potato: Usually no growth.

Blood serum shows scant growth.

No gas from carbohydrates. Acid from glucose, galactose, fructose, lactose and more slowly from mannose and cellobiose. No acid from arabinose, xylose, rhamnose, maltose, melibiose, sucrose, trehalose, raffinose, melezitose, dextrin, starch, inulin, amygdalin, salicin, glycerol, erythritol, adonitol, mannitol, sorbitol, dulcitol or inositol.

Esculin not hydrolyzed.

Hydrogen sulfide produced.

Voges-Proskauer test negative.

Methyl red test negative.

Methylene blue-reduction test negative.

Narrow green zone of hemolysis develops around deep colonies on blood agar.

Catalase negative.

Out of 43 strains studied serologically (Watts, Jour. Path. and Bact., *50*, 1940, 355), 38 appeared to be of one antigenic group, and 5 of another.

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* **Revised by Prof. Robert S. Breed, New York State Experiment Station, August, 1938; further revision, January, 1945.**

Optimum pH 7.6.

Microaerophilic.

Optimum temperature 37°C.

Source: From cases of swine erysipelas.

Habitat: The cause of swine erysipelas. Transmissible to gray and white mice, rabbits and pigeons. Has been transmitted to man by accidental inoculation.

2. **Erysipelothrix muriseptica** (Flügge) Rosenbach. (Bacillus der Mäuseseptikämie, Koch, Mittheil. a. d. kaiserl. Gesundheitsamte, *1*, 1881, 93; *Bacillus insidiosus* Trevisan, Car. di alc. nuov. gen. di Batter., 1885, 10; *Bacillus murisepticus* Flügge, Die Mikroorganismen, 2 Aufl., 1886, 250; *Bacillus murinus* Schroeter, in Cohn, Kryptogamen Flora v. Schlesien, *3*, 1886, 162; *Bacterium murisepticum* Migula, in Engler and Prantl, Die natürl. Pflanzenfam., *1*, la, 1895, 24; *Mycobacterium murisepticum* Chester, Manual Determ. Bact., 1901, 353; Rosenbach, Ztschr. f. Hyg., *63*, 1909, 367; *Pasteurella muriseptica* Bergey et al., Manual, 1st ed., 1923, 265; not *Pasturella muriseptica* Topley and Wilson, Princip. Bact. and Immun., *1*, 1931, 482.) From Latin *mus*, *muris*, a mouse; Greek *septicus*, putrefying, septic.

Rods: 0.5 by 0.8 to 1.0 micron, occurring singly. Non-motile. Gram-positive.

Gelatin colonies: Very small, whitish, dew-like, with indefinite margin.

Gelatin-stab: Filiform growth in stab, arborescent. No liquefaction.

Agar slant: Very slight, clear, dew-like streak.

Litmus milk: Unchanged.

Potato: No growth.

Indole not formed.

Nitrites not produced from nitrates.

Microaerophilic.

Optimum temperature 37°C.

Source: From cases of mouse septicemia.

Habitat: In fatal septicemia in white mice following injection of putrid meat infusion. Not infectious for field mice.

3. **Erysipelothrix erysipeloidis** (Lehmann and Neumann) Rosenbach. (Cladothrix des Erythema migrans, Rosenbach, Arch. klin. Chirurg., *36*, 1887, 2; *Oospora rosenbachi* Sauvagais and Radais, 1892, according to Brumpt, Précis de Parasit., Paris, 4th ed., 1927, 1201; *Oospora erysipeloidis* Lehmann and Neumann, Bakt. Diag., 1 Aufl., *2*, 1896, 392; *Streptothrix rosenbachii* Kruse in Flügge, Die Mikroorganismen, 3 Aufl., *2*, 1896, 61; *Actinomyces erysipeloidis* Lachner-Sandoval, Ueber Strahlenpilze Strassburg, 1898, 64; *Discomyces rosenbachi* Gedoelst, Champ. Paras. Homme, 1902, 177; *Streptothrix erysipeloides* Caminiti, Cent. f. Bakt., I Abt., Orig., 1907, 198; Rosenbach, Ztschr. f. Hyg., *63*, 1909, 367; *Nocardia rosenbachi* Castellani and Chalmers, Man. Trop. Med., 2nd ed., 1913, 815; *Babesia erysipeloides* Chalmers and Christopherson, Ann. Trop. Med. and Parasit., *10*, 1916, according to Nannizzi, in Pollacci, Tratt. Micopat. Umana, *4*, 1934, 45; *Actinomyces rosenbachii* Holland, Jour. Bact., *5*, 1920, 216; *Bacterium erysipeloidis* Lehmann and Neumann, Bakt. Diag., 7 Aufl., *2*, 1927, 499.) From Greek *erysipelas*, erysipelas; *idus*, shape, appearance.

Rosenbach (*loc. cit.*) made a comparative study of the three species in this genus and came to the conclusion that they were different, although closely allied to each other. However, Rickmann (Ztschr. f. Hyg., *64*, 1909, 362) concluded that they were identical.

Source: Isolated by Rosenbach (Verhandl. d. deutsch. Gesellsch. f. Chirurg., *2*, 1887, 75) in cases of human erysipeloid.

FAMILY IX. ACHROMOBACTERIACEAE BREED.

(Jour. Bact., *50*, 1945, 124.)

Rods, small to medium in size, cells usually uniform in shape. No branching on ordinary media, if at all. Gram-negative, rarely Gram-variable. Peritrichous or non-motile. Growth on agar slants non-chromogenic to grayish-yellow, brownish-yellow or yellow to orange. The pigment does not diffuse through the agar. Characterized by lack of power or feeble powers of attacking carbohydrates. May form acid from hexoses but no gas. May or may not reduce nitrates. May or may not liquefy gelatin. Do not liquefy agar or attack cellulose, and are not phosphorescent. Litmus milk may become faintly acid but not sufficiently acid to curdle. Usually the reaction remains unchanged or becomes alkaline. Generally salt water, fresh water and soil forms and, less commonly, parasites. Some plant pathogens may belong here.

Key to the genera of family **Achromobacteriaceae.**

I. Non-chromogenic or at most little or no chromogenesis on agar or gelatin media.
   A. Litmus milk turned alkaline. No acid from carbohydrates.

      Genus I. *Alcaligenes*, p. 412.

   B. Litmus milk slightly acid (never curdled), unchanged or alkaline. Acid usually produced from hexose sugars.

      Genus II. *Achromobacter*, p. 417.

II. Produces yellow to orange chromogenesis.

   A. Litmus milk slightly acid (never curdled) unchanged or alkaline. Acid usually produced from hexose sugars.

      Genus III. *Flavobacterium*, p. 427.

Genus I. **Alcaligenes** *Castellani and Chalmers.**

(Manual Trop. Med., 3rd ed., 1919, 936.) From M.L., alkali and Latin *genio*, to produce.

Peritrichous to monotrichous, or non-motile rods. Gram-negative to Gram-variable. Do not produce acid or gas from carbohydrates. May or may not liquefy gelatin and solidified blood serum. Turn litmus milk alkaline and may or may not peptonize it. Do not form acetylmethylcarbinol. Chromogenesis when it occurs is grayish-yellow, brownish-yellow or yellow. Generally occur in the intestinal tract of vertebrates or in dairy products.

The type species is *Alcaligenes faecalis* Castellani and Chalmers.

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* Revised by Prof. H. J. Conn, New York State Experiment Station, Geneva, New York, June, 1938; further revision by Prof. Robert S. Breed, New York State Experiment Station, Geneva, New York, June, 1945.

Key to the species of genus **Alcaligenes.**

I. Gelatin not liquefied.
  A. Motile.
    1. Does not produce ropiness in milk. Found in the intestinal tract.
      1. *Alcaligenes faecalis.*
    2. Produces ropiness in milk.
      2. *Alcaligenes viscosus.*
  B. Non-motile.
    1. Found in the intestinal tract.
      3. *Alcaligenes metalcaligenes.*

II. Gelatin liquefied.
  A. Motile.
    1. Milk peptonized; blood serum liquefied.
      4. *Alcaligenes bookeri.*
    2. Milk not peptonized; blood serum not liquefied.
      5. *Alcaligenes recti.*
  B. Non-motile.
    1. Milk peptonized, slimy.
      6. *Alcaligenes marshallii.*

1. **Alcaligenes faecalis** Castellani and Chalmers. (*Bacillus faecalis alcaligenes* Petruschky, Cent. f. Bakt., I Abt., *19*, 1896, 187; *Bacterium fecalis alcaligenes* Chester, Ann. Rept. Del. Col. Agr. Exp. Sta., *9*, 1897, 73; *Bacterium alcaligenes* Lehmann and Neumann, Bakt. Diag., 2 Aufl., 1899, 242; *Bacillus alcaligenes* Migula, Syst. d. Bakt., *2*, 1900, 737; Castellani and Chalmers, Manual Trop. Med., 1919, 936; *Bacillus fecalis-alcaligenes* Holland, Jour. Bact., *5*, 1920, 218; *Bacterium fecalis-alcaligenes* Holland, *ibid.*; *Vibrio alcaligenes* Lehmann and Neumann, Bakt. Diag., 7 Aufl., *2*, 1927, 548: *Bacterium faecale alcaligenes* Monias, Jour. Inf. Dis., *43*, 1928, 330.) From Latin *faex*, dregs; M. L., fecal.

Rods: 0.5 by 1.0 to 2.0 microns, occurring singly and in pairs, and occasionally in long chains. Motile with peritrichous flagella. In some strains, the majority of the individual cells show only a single flagellum. This is apt to be in a lateral rather than in the polar position. Gram-negative.

Gelatin colonies: Circular, grayish, translucent.

Gelatin stab: Gray surface growth. No liquefaction.

Agar colonies: Transparent with opaque center, undulate margin.

Agar slant: White, glistening, opalescent, undulate margin.

Broth: Turbid, with thin pellicle, and viscid sediment. Gives off ammonia.

Litmus milk: Alkaline.

Potato: Scanty to abundant, yellowish to brownish growth.

Indole not formed.

Nitrite production from nitrates variable.

No acid or gas from carbohydrate media.

No characteristic odor.

Aerobic, facultative.

Optimum temperature 37°C.

Source: Feces, abscesses related to intestinal tract, occasionally blood stream.

Habitat: Intestinal canal. Generally considered non-pathogenic.

1a. *Alcaligenes faecalis* var. *radicans* Evans (Public Health Rpts., *46*, 1931, 1676) is a gelatin liquefying strain.

2. **Alcaligenes viscosus** (Weldin and Levine) Weldin. (*Bacillus lactis viscosus* Adametz, Cent. f. Bakt., *9*, 1891, 698; *Bacillus viscosus lactis* Kruse, in Flügge, Die Mikroorganismen, *2*, 1896, 359; *Bacterium viscosus lactis* Chester, Delaware Agr. Exp. Sta. 9th Ann. Rept., 1897, 89; *Bacterium lactis viscosum* Lehmann and Neumann, Bakt. Diag., 1 Aufl., *2*, 1896, 198 (Eng. ed., 1901, 196); *Bacterium subviscosum* Migula, Syst. d. Bakt., *2*, 1900, 326; Group I, varieties 1, 2, 3, 4 and 5 of Harrison, Rev. Gén. du Lait, *5*, 1905, 100; *Bacterium visco-coccoidium* Buchanan and Hammer, Iowa Agr. Exp. Stat. Research Bull. 22, 1915, 260; *Bacillus lactis-viscosus* Holland, Jour. Bact., *5*, 1920, 218; *Bacterium lactis-viscosus* Holland, *idem*; *Bacterium viscosum* Weldin and Levine, Abst. Bact., *7*, 1923, 16 (not *Bacterium viscosum* Migula, Syst. d. Bakt., *2*, 1900, 647); *Lactobacillus viscosus* Bergey et al., Manual, 1st ed., 1923, 244; *Achromobacter viscosum* Bergey et al., Manual, 2nd ed., 1925, 169; Weldin, Iowa State College Jour. Sci., *1*, 1927, 186.) From Latin *viscosus*, viscous.

Description taken largely from Long and Hammer, Iowa State Coll. Jour. of Sci., *10*, 1936, 262.

Rods: 0.6 to 1.0 by 0.8 to 2.6 microns, almost spherical cells frequently found, occurring singly, in pairs or short chains. Motile (Adametz, *loc. cit.*); non-motile (Long and Hammer, *loc. cit.*). Gram-negative, rarely Gram-positive. Capsules produced in milk cultures.

Gelatin colonies: Small, gray becoming yellowish.

Gelatin stab: White surface growth with villous growth in stab. No liquefaction.

Agar colonies: After 3 to 4 days, circular, 4 to 6 mm in diameter, white, viscid, shining, edge entire.

Agar slant: Abundant, white, spreading, viscid, shining.

Broth: Turbid with thin pellicle and some sediment. Ropiness generally produced.

Litmus milk: Ropiness produced. Pellicle formed. Alkaline. No coagulation.

Potato: Moderately heavy, dirty-white, spreading, shining growth.

Indole not formed.

Nitrites ordinarily not produced or produced only in a trace from nitrates.

No H_2S produced.

Slight, if any, acid production from carbohydrates.

Fat is hydrolyzed.

Methyl red reaction negative.

Voges-Proskauer reaction negative.

Temperature relations: Growth occurs at 10° and at 20°C. At 37° and at 40°C growth variable.

Aerobic.

Source: Originally isolated from water.

Habitat: Found in water and around dairy barns, dairy utensils. Produces ropiness in milk.

Long and Hammer (Iowa State Coll. Jour. Sci., *10*, 1936, 264) have described a variety of this species (*Alcaligenes viscosus* var. *dissimilis*) which does not produce ropiness in milk.

3. **Alcaligenes metalcaligenes** Castellani and Chalmers. (Castellani and Chalmers, Man. Trop. Med., 1919, 936; *Bacterium metalcaligenes* Weldin and Levine, Abst. Bact., *7*, 1923, 13; *Achromobacter metalcaligenes* Bergey et al., Manual, 2nd ed., 1925, 169.) From Greek *meta*, in common with; M. L., resembling *alcaligenes*.

Rods: 0.6 by 1.5 microns, with rounded ends, occurring singly and in pairs. Non-motile. Gram-negative.

Gelatin stab: No liquefaction.

Agar colonies: Circular, raised, smooth, amorphous, entire, gray.

Agar slant: Gray, scanty, filiform, contoured, viscid.

Broth: Membranous pellicle with heavy sediment.

Litmus milk: Alkaline.

Potato: Scanty, glistening, smooth, sometimes faint pink.

Indole not formed.

Nitrite production from nitrates variable.

Starch not hydrolyzed.

Blood serum not liquefied.

No action on carbohydrates.

Aerobic, facultative.

Optimum temperature 22°C.

Habitat: Intestinal canal.

4. **Alcaligenes bookeri** (Ford) Bergey et al. (Bacillus A of Booker, Trans. Ninth Internat. Med. Congress, *3*, 1887, 598; *Bacillus bookeri* Ford, Studies from the Royal Victoria Hospital, Montreal, *1*, 1903, 31; Bergey et al., Manual, 1st ed., 1923, 236; *Bacterium bookeri* Levine and Soppeland, Eng. Exp. Sta., Iowa State College, Bul. 77, 1926, 55.) Named for the bacteriologist who first isolated this species.

Rods: 0.5 by 1.5 to 2.0 microns, occurring singly. Motile with peritrichous flagella. Gram-negative.

Gelatin colonies: Circular, brown, variable in size.

Gelatin stab: Slow, saccate liquefaction, becoming stratiform.

Agar colonies: Thin, transparent, with opaque center and indistinct margin.

Agar slant: Abundant, yellowish to yellowish-brown.

Broth: Turbid, with viscid sediment. No pellicle.

Litmus milk: Alkaline. Soft curd. Litmus reduced. Peptonization.

Potato: Luxuriant, yellowish-white, moist. Medium is darkened.

Indole not formed.

Nitrites not produced from nitrates.

No acid or gas from carbohydrate media.

Blood serum: Yellowish-brown growth. Gradual liquefaction.

No characteristic odor.

Aerobic, facultative.

Optimum temperature 37°C.

Source: From alvine discharges of children suffering with cholera infantum.

Habitat: Intestinal canal.

5. **Alcaligenes recti** (Ford) Bergey et al. (*Bacterium recti* Ford, Studies from the Royal Victoria Hospital, Montreal, *1*, 1903, 31; Bergey et al., Manual, 1st ed., 1923, 236.) From Latin *rectus*, rectum.

Rods: 0.5 by 1.5 to 2.0 microns, occurring singly, in pairs and in chains. Motile with peritrichous flagella. Gram-negative.

Gelatin colonies: Variable in size and shape, circular to oval, brown.

Gelatin stab: Rapid, saccate liquefaction.

Agar colonies: Large, grayish-white, with opaque center. Slightly spreading.

Agar slant: Grayish-white, echinulate.

Broth: Turbid. No pellicle.

Litmus milk: Alkaline. No peptonization.

Potato: Luxuriant, moist, brownish-red.

Indole not formed.

Nitrites produced from nitrates.

No acid or gas from carbohydrate media.

Blood serum: Abundant white growth. No liquefaction.

No characteristic odor.

Aerobic, facultative.

Optimum temperature 37°C.

Source: Found but once from coecum and rectum (Ford).

Habitat: Intestinal canal.

6. **Alcaligenes marshallii** Bergey et al. (Bacillus B of Marshall, Cent. f. Bakt., II Abt., *11*, 1903, 739; *Bacterium lactis marshalli* Conn, Esten and Stocking, Ann. Rept. Storrs Agr. Exp. Station, 1906, 141; Bergey et al., Manual, 1st ed., 1923, 237.) Named for Prof. C. E. Marshall, the American bacteriologist who first isolated this species.

Rods: 0.3 by 1.2 microns, occurring singly. Non-motile. Gram-negative.

Gelatin colonies: Gray, granular, irregular, glistening.

Gelatin stab: Slow, infundibuliform liquefaction.

Agar slant: Filiform, gray to creamy-white, raised, becoming lemon-yellow.

Broth: Turbid, with gray ring and viscid sediment.

Litmus milk: Alkaline, slimy, peptonized, strong odor.

Potato: Luxuriant, lemon-yellow, smooth.

Indole not formed.

Nitrites not produced from nitrates.

No acid or gas from carbohydrates.

Aerobic, facultative.

Optimum temperature 30°C.

Habitat: Milk.

Appendix: The following species have also sometimes been regarded as belonging in the genus *Alcaligenes*, or possess characters that indicate that they belong in this genus.

Achromobacter alcaliaromaticum (Berlin) Bergey et al. (*Bacterium alcaliaromaticum* Berlin, Rev. de Microbiol. et Epidemiol., *6*, 1927; Bergey et al., Manual, 3rd ed., 1930, 212.) From feces. See Manual, 5th ed., 1939, 509 for a description of this species. This species is much like *Alcaligenes faecalis*.

Achromobacter cystinovorum Barber and Burrows. (Biochem. Jour., 30, 1936, 599.) From soil. See Manual, 5th ed., 1939, 516 for a description of this species. This species is much like *Alcaligenes marshallii*.

Achromobacter lipidis (Anderson) Allison, Anderson and Cole. (*Bacterium lipidis* Anderson, Internat. Assoc. Milk Dealers, Proc. 30th Ann. Convention, Labora ory Section, October, 1937, 19; Allison, Anderson and Cole, Jour. Bact., *36*, 1938, 571.) From rancid cream. See Manual, 5th ed., 1934, 521 for a description of this species. This species is much like *Alcaligenes metalcaligenes*.

Alcaligenes albus Bergey et al. (*Bacterium lactis album* Conn, Esten, and Stocking, Ann. Rept., Storrs Agr. Exp. Station, 1906, 143; Bergey et al., Manual, 1st ed., 1923, 237.) From udder of cow. Gram-positive. See Manual, 5th ed., 1939, 100 for a description of this species.

Alcaligenes alcalinofoetidus Hauduroy et al. (*Bacillus alcalinofoetidus* Castellani, Jour. Trop. Med., 1930, 134; Hauduroy, Ehringer, Urbain, Guillot and Magrou, Dictionnaire des bactéries pathogènes. Paris, 1937, 29.) From tonsils of persons having an offensive breath.

Alcaligenes ammoniagenes (Cooke and Keith) Bergey et al. (*Bacterium ammoniagenes* Cooke and Keith, Jour. Bact., *13*, 1927, 315; Bergey et al., Manual, 3rd ed., 1930, 367.) From feces of infants. Gram-positive. See Manual, 5th ed., 1939, 99 for a description of this species.

Alcaligenes denieri Corbet. (Organism No. 6, Denier and Vernet, Le Caoutchouc, *17*, 1920, 10193; Quart. Jour. Rubber Research Inst., Malaya, *2*, 1930, 152.) From the latex of *Hevea brasiliensis* (para rubber tree). Gram-positive. See Manual, 5th ed., 1939, 99, for a description of this species.

Alcaligenes faecalis var. *mariense* Hauduroy et al. (*Bacillus mariense* Klimenko quoted from Besson, Technique Microbiologique, p. 904; Hauduroy et al., Dict. Path. Bact., Paris, 1937, 31.) A hydrogen sulfide producing variety.

Alcaligenes lenis De Assis. (Boletim do Inst. Vital Brasil, Niteroi, No. 14, 1930, 1.) From human blood stream.

Alcaligenes stevensae Brown. (Amer. Museum Novit., No. 251, 1927, 6.) From crushed egg masses of the moth (*Malacosoma americana*). Said to be related to *Alcaligenes bronchisepticus*.

Bacillus coeci Ford. (Ford, Studies from Royal Victoria Hosp., Montreal, *1*, No. 5, 1903, 45.) Found in stomach and rectum of a single human subject. Much like *Alcaligenes bookeri*.

Bacillus pylori Ford. (Ford, Studies from Royal Victoria Hosp., Montreal *1*, No. 5, 1903, 44.) Found in the human stomach. Liquefied gelatin and peptonized casein but did not liquefy blood serum.

Flavobacterium fecale Bergey et al. (*Bacillus fecale aromaticum* Stutzer, Cent. f. Bakt., I Abt., Orig., 91, 1923, 87; Bergey et al., Manual, 3rd ed., 1930, 150.) From feces. Resembles *Alcaligenes marshallii*. See Manual, 5th ed., 1939, 545 for a description of this species.

Genus II. **Achromobacter** *Bergey et al.**

(Bergey et al., Manual, 1st ed., 1923, 132; *Achromobacterium* Richards, Proc. Soc. Agr. Bact. (British), 15th Ann. Conf., 1944, 14.) From Greek *achroma*, without color and *bactrum*, a staff or rod.

Non-pigment-forming (at most no pigment formed on agar or gelatin) rods. Motile with peritrichous flagella or non-motile. Gram-negative to Gram-variable. Litmus milk faintly acid to unchanged or alkaline. Occur in salt to fresh water and in soil.

The type species is *Achromobacter liquefaciens* (Eisenberg) Bergey et al.

Key to the species of genus **Achromobacter.**

I. Motile. Flagella peritrichous.
- A. Gelatin liquefied.
  - 1. Litmus milk unchanged.
    - a. Nitrites not produced from nitrates.
      - 1. *Achromobacter liquefaciens.*
    - aa. Nitrites are produced from nitrates.
      - 2. *Achromobacter thalassius.*
      - 3. *Achromobacter iophagum.*
  - 2. Litmus milk acid.
    - a. Nitrites are produced from nitrates.
      - 4. *Achromobacter delicatulum.*
- B. Gelatin not liquefied.
  - 1. Litmus milk unchanged.
    - a. Nitrites are produced from nitrates.
      - 5. *Achromobacter aquamarinus.*
      - 6. *Achromobacter cycloclastes.*
  - 2. Litmus milk slightly acid.
    - a. Nitrites not produced from nitrates.
      - 7. *Achromobacter superficiale.*

II. Non-motile.
- A. Gelatin liquefied.
  - 1. Litmus milk unchanged.
    - a. Nitrites slowly produced from nitrates.
      - 8. *Achromobacter stenohalis.*
    - aa. Nitrites not produced from nitrates.
      - 9. *Achromobacter butyri.*
  - 2. Litmus milk alkaline.
    - a. Nitrites are produced from nitrates.
      - 10. *Achromobacter stationis.*
- B. Gelatin not liquefied.
  - 1. Litmus milk unchanged.
    - a. Action on nitrates not recorded.
      - 11. *Achromobacter eurydice.*
  - 2. Litmus milk acid, reduced in 5 days.
    - a. Nitrites are produced from nitrates.
      - 12. *Achromobacter delmarvae.*

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* Partially rearranged before his death by Prof. D. H. Bergey, Philadelphia, Pennsylvania, September, 1937; further revision by Prof. Robert S. Breed, New York State Experiment Station, Geneva, New York, August, 1945.

1. **Achromobacter liquefaciens** (Eisenberg) Bergey et al. (*Bacillus liquefaciens* Eisenberg, Bakt. Diag., 3 Aufl., 1891, 112; not *Bacillus liquefaciens* Doyen, Jour. d. connaiss. médic., 1889, 108; not *Bacillus liquefaciens* Lucet, Ann. Inst. Past., 7, 1893, 327; not *Bacillus liquefaciens* Migula, Syst. d. Bakt., *2*, 1900, 723; *Bacillus sternbergii* Migula, Syst. d. Bakt., *2*, 1900, 726; Bergey et al., Manual, 1st ed., 1923, 135.) From Latin, liquefying.

Description emended by Bergey et al. (*loc. cit.*). This is reported to be a common water organism by Lustig (Diag. d. Bakt. des Wassers, 1893, 86), by Frankland and Frankland (Microorganisms in Water, 1894, 461) and by Horrocks (Bact. Exam. of Water, 1901, 54).

Short, rather thick rods, with rounded ends, occurring singly. Motile, possessing peritrichous flagella. Gram-negative.

Gelatin colonies: Circular, gray, entire, slimy. Liquefaction. In time a putrid odor.

Gelatin stab: Napiform liquefaction.

Agar slant: Dirty-white, spreading growth.

Broth: Turbid.

Litmus milk: Unchanged.

Potato: Light yellow streak.

Indole not formed.

Nitrites not produced from nitrates.

Aerobic, facultative.

Optimum temperature 20° to 25°C.

Habitat: Water.

2. **Achromobacter thalassius** ZoBell and Upham. (Bull. Scripps Inst. of Oceanography, Univ. Calif., *5*, 1944, 279.) From Greek *thalassius*, marine, of the sea.

Rods: 0.6 to 0.7 by 0.8 to 2.3 microns, with some variation in shape, occurring singly, in pairs and short chains and many cells lying side by side. Motile by means of peritrichous flagella. Gram-negative but cell walls tend to retain stain.

All media except the fresh-water broth, litmus milk, and potato were prepared with sea water.

Gelatin colonies: 1 mm, circular, white.

Gelatin stab: Napiform liquefaction. Filiform growth along line of stab.

Agar colonies: Punctiform, rough, translucent, raised.

Agar slant: Moderate, glistening, beaded, watery, butyrous growth with no pigment.

Sea-water broth: No pellicle, slight turbidity, scanty powdery sediment.

Fresh-water broth: Fair growth.

Litmus milk: No visible change. Casein not digested.

Potato: No visible growth.

Indole not formed.

Nitrites are produced from nitrates.

Does not ferment glucose, lactose, maltose, sucrose, xylose, mannitol, glycerol, or salicin.

Starch not hydrolyzed.

Hydrogen sulfide not formed.

Ammonia produced from peptone but not from urea.

Fats not hydrolyzed.

Aerobic, facultative.

Optimum temperature 20° to 25°C.

Source: Marine bottom deposits.

3. **Achromobacter iophagum** (Gray and Thornton) Bergey et al. (*Bacterium iophagum* Gray and Thornton, Cent. f. Bakt., II Abt., *78*, 1928, 89; Bergey et al., Manual, 3rd ed., 1930, 204.) From Greek *ius*, a poison and *phagein*, to eat or devour.

Rods: 0.8 to 1.0 by 1.0 to 5.0 microns. Motile by means of peritrichous flagella. Gram-negative.

Gelatin colonies: Quickly liquefied.

Gelatin stab: Liquefied.

Agar colonies: Circular or amoeboid, whitish, flat, raised, smooth, translucent, entire.

Agar slant: Filiform, white to buff, flat, undulate.

Broth: Turbid.

Litmus milk: Unchanged.

Nitrites produced from nitrates.

Starch hydrolyzed.

Acid from glucose and sucrose. Occasionally from maltose and glycerol.

Attacks phenol and naphthalene.

Aerobic, facultative.

Optimum temperature 30° to 35°C.

Source: Fifteen cultures from soil.

Habitat: Soil.

4. **Achromobacter delicatulum** (Jordan) Bergey et al. (*Bacillus delicatulus* Jordan, Report Mass. State Bd. of Health, 1890, 837; *Bacterium delicatulus* Chester, Ann. Rept. Del. Col. Agr. Exp. Sta., *9*, 1897, 82; Bergey et al., Manual, 1st ed., 1923, 137.) From Latin *delicatus*, soft, delicate; M. L. *delicatulus*, somewhat delicate.

Characters added to Jordan's description by Bergey (*loc. cit.*) from his private notes are indicated. Steinhaus (Jour. Bact., *42*, 1941, 771) apparently found the same organism and has added other characters.

Rods: 1.0 by 2.0 microns, occurring singly (Jordan). Motile, possessing peritrichous flagella. Gram-negative (Bergey).

Gelatin colonies: Whitish, homogeneous, with radiate margin.

Gelatin stab: Infundibuliform liquefaction.

Agar slant: Whitish, glistening.

Broth: Turbid, with gray pellicle and sediment.

Litmus milk: Acid. Slow reduction and peptonization (Steinhaus).

Potato: Thin, gray streak.

Acid from glucose, sucrose, maltose and lactose (slow) (Steinhaus).

No hydrolysis of starch (Steinhaus).

No H_2S produced (Steinhaus).

Indole not formed (Bergey).

Nitrites produced from nitrates.

Aerobic, facultative.

Optimum temperature 30° to 35°C.

Source: From the effluent of a septic tank (Jordan). From water (Bergey). From the alimentary tract of an adult Colorado potato beetle (*Leptinotarsa decemlineata* Say) (Steinhaus).

Habitat: Presumably widely distributed in nature.

5. **Achromobacter aquamarinus** ZoBell and Upham. (Bull. Scripps Inst. of Oceanography, Univ. Calif., *5*, 1944, 264.) From Latin *aqua*, water, and *marinus*, sea.

Rods: 0.8 by 1.2 to 2.0 microns, with rounded ends, occurring singly. Motile by means of a few peritrichous flagella. Gram-negative.

All media except the fresh-water broth, litmus milk, and potato were prepared with sea water.

Gelatin colonies: 2 mm, convex, circular, entire, whitish.

Gelatin stab: Poor growth, no liquefaction, no pigment.

Agar colonies: 2 mm, convex, smooth, circular.

Agar slant: Moderate, beaded, glistening, butyrous growth with no pigment.

Sea-water broth: Surface ring, moderate turbidity, heavy viscous sediment.

Fresh-water broth: Poor growth.

Litmus milk: No visible change. Casein not digested.

Potato: No visible growth.

Indole not formed.

Nitrites rapidly produced from nitrates.

Produces acid but no gas from glucose and maltose. Does not ferment lactose, sucrose, mannitol, glycerol, xylose, or salicin.

Starch not hydrolyzed.

Hydrogen sulfide not formed.

Ammonia produced from peptone but not from urea.

Fats are hydrolyzed.

Aerobic, facultative.

Optimum temperature 20° to 25°C.

Source: Found in sea water and on submerged slides.

Habitat: Sea water.

6. **Achromobacter cycloclastes** (Gray and Thornton) Bergey et al. (*Bacterium cycloclastes* Gray and Thornton, Cent. f. Bakt., II Abt., *73*, 1928, 89; Bergey et al., Manual, 3rd ed., 1930, 212.) From Greek *cyclus*, ring and *clastus*, breaking in pieces.

Rods: 1.0 to 1.5 by 1.5 to 8.0 microns. Motile with 1 to 12 peritrichous flagella. Gram-negative.

Gelatin colonies: Circular, white, raised, smooth, glistening, entire.

Gelatin stab: No liquefaction. Nail head growth.

Agar colonies: Circular to amoeboid, white, flat to convex, smooth, glistening, translucent with opaque center, entire.

Agar slant: Filiform, pale buff, raised, smooth, glistening, undulate.

Broth: Turbid.

Nitrites produced from nitrates.

Starch not hydrolyzed.

Litmus milk unchanged.

No acid from carbohydrate media.

Attacks phenol and naphthalene.

Aerobic, facultative.

Optimum temperature 30° to 35°C.

Source: Three cultures from soil.

Habitat: Soil.

7. **Achromobacter superficiale** (Jordan) Bergey et al. (*Bacillus superficialis* Jordan, Report Mass. State Bd. of Health, 1890, 833; *Bacterium superficialis* Chester, Ann. Rept. Del. Col. Agr. Exp. Sta., *9*, 1897, 94; Bergey et al., Manual, 1st ed., 1923, 144.) From Latin *superficialis*, lying on the surface.

Characters added to Jordan's description by Bergey (*loc. cit.*) from his private notes are indicated.

Rods: 1.0 by 2.2 microns, occurring singly (Jordan). Motile, possessing peritrichous flagella. Gram-negative (Bergey).

Gelatin colonies: Small, circular, gray, translucent.

Gelatin stab: Scanty surface growth. Slow liquefaction.

Agar slant: Limited, gray, filiform.

Broth: Slightly turbid.

Litmus milk: No change. Later becoming slightly acid.

Potato: No growth (Jordan). Limited growth (Bergey). Abundant (Steinhaus).

Indole not formed (Bergey).

Nitrites not produced from nitrates.

Aerobic, facultative.

Optimum temperature 25° to 30°C.

Source: Sewage. Gibbons (Contrib. to Canadian Biol. and Fish., *8*, No. 22, 1934, 279) reports this species as occurring in the slime and feces of the cod (*Gadus callarias*) and dogfish (*Squalus acanthias*). An organism apparently identical with this organism has been found by Steinhaus (Jour. Bact., *42*, 1944, 771) in the intestines of beetle larvae (*Urographus fasciata* DeG.).

Habitat: Presumably widely distributed in nature.

8. **Achromobacter stenohalis** ZoBell and Upham. (Bull. Scripps Inst. of Oceanography, Univ. Calif., *5*, 1944, 257.) From Greek *stenus*, narrow or close, and *halinus*, salty; adapted to a slight change of salinity only.

Rods: 0.8 to 0.9 by 0.8 to 1.6 microns, occurring singly, in pairs and short chains. Non-motile. Capsulated. Gram-negative.

All media except the fresh-water broth, litmus milk, and potato were prepared with sea water.

Gelatin colonies: 1 mm, whitish, circular, convex, entire. No pigment.

Gelatin stab: Very slow crateriform liquefaction. Napiform in 50 days.

Agar colonies: Small, circular, opalescent, lobate edge, convex with slightly raised margin, smooth.

Agar slant: Moderate, beaded, glistening, opalescent, beaded growth with no pigment.

Sea-water broth: Moderate turbidity, viscid sediment, no pellicle or ring.

Fresh-water broth: No visible growth.

Litmus milk: No visible change. Casein not digested.

Potato: No visible growth.

Indole not produced.

Nitrites slowly produced from nitrates.

No acid or gas from glucose, lactose, maltose, sucrose, mannitol, glycerol, xylose, or salicin.

Starch not hydrolyzed.

Hydrogen sulfide not produced.

Ammonia produced from peptone but not from urea.

Fats are not hydrolyzed.

Aerobic, facultative (poor anaerobic growth).

Optimum temperature 20° to 25°C.

Source: Sea water, marine mud, and marine phytoplankton.

Habitat: Sea water.

9. **Achromobacter butyri** Bergey et al. (*Micrococcus butyri-aromafaciens* Keith, The Technology Quarterly, *10*, 1897, 247; *Bacillus butyri aromafaciens* Grimm, Cent. f. Bakt., II Abt., *8*, 1902, 589; Bergey et al., Manual, 1st ed., 1923, 148; *Bacterium butyriaromafaciens* Omeliansky, Jour. Bact., *8*, 1923, 400.) From Latin *butyrum*, butter.

Rods: 0.5 to 1.0 micron, nearly spherical, occurring singly and in pairs. Non-motile. Gram-negative.

Gelatin colonies: White, circular, smooth, glistening.

Gelatin stab: White surface growth, liquefaction with white sediment.

Agar slant: Abundant, white, glistening.

Broth: Turbid, with ring and sediment.

Litmus milk: Reaction unchanged. Aromatic odor.

Potato: Slow and limited, white growth.

Nitrites not produced from nitrates.

Aerobic, facultative.

Optimum temperature 25°C.

Habitat: Milk.

10. **Achromobacter stationis** ZoBell and Upham. (Bull. Scripps Inst. of Oceanography, Univ. Calif., *5*, 1944, 273.) From Latin *statio*, anchorage.

Ovoid rods: 0.4 by 0.5 to 0.6 microns, occurring singly or in chains of two to three. Non-motile. Gram-positive but easily destained.

All media except the fresh-water broth, litmus milk, and potato were prepared with sea water.

Gelatin colonies: 0.5 to 1 mm, circular, convex, grayish-white.

Gelatin stab: Very slow napiform liquefaction.

Agar colonies: 1 to 2 mm, convex, lobate edge, smooth, colorless.

Agar slant: Moderate, glistening, filiform, butyrous growth with no pigment.

Sea-water broth: Heavy pellicle, no turbidity, granular growth along walls, scanty sediment.

Fresh-water broth: Good growth.

Litmus milk: Becomes alkaline. Casein not digested.

Potato: No visible growth.

Indole not formed.

Nitrites rapidly produced from nitrates.

Produces acid but no gas from glucose. Does not ferment lactose, maltose, sucrose, mannitol, glycerol, xylose, or salicin.

Starch not hydrolyzed.

Hydrogen sulfide not formed.

Ammonia produced from peptone but not from urea.

Fats not hydrolyzed.

Aerobic, facultative.

Optimum temperature 20° to 25°C.

Source: Found in film of marine fouling organisms.

Habitat: Sea water.

11. **Achromobacter eurydice** (White) Bergey et al. (*Bacterium eurydice* White, U. S. Dept. of Agr., Bur. of Entomol., Circ. 157, 1912, 3 and U. S. Dept. of Agr. Bull. 810, 1920, 15; Bergey et al., Manual, 2nd ed., 1925, 170.) From Greek *Eurydice*, the wife of Orpheus.

Rods: Small, slender, with slightly rounded ends, occurring singly and in pairs. Non-motile. Gram-negative.

Gelatin stab: A bluish-gray growth occurs along the line of inoculation. No liquefaction.

Glucose agar colonies: Bluish-gray, circular, smooth, glistening, entire.

Broth: Uniform turbidity with viscid sediment.

Litmus milk: Unchanged.

Acid from glucose but little or no action on other carbohydrates.

Potato: Slight, grayish growth.

Aerobic, facultative.

Innocuous when fed to bees. Not pathogenic when inoculated subcutaneously in rabbits.

Source: Occurs as a secondary invader in European foulbrood of bees.

Habitat: Unknown.

12. **Achromobacter delmarvae** Smart. (Smart, Jour. Bact., *23*, 1932, 41 and Jour. Agr. Research, *51*, 1935, 363.) From *Delmarva*, coined from Del., Mar. and Va., the regions in which the species was found.

Short rods: Average size 0.75 by 1.5 microns, with rounded ends, occurring singly, in pairs and in short chains. Non-motile. Gram-negative.

Gelatin colonies: Similar to agar colonies.

Gelatin stab: Scanty growth. No liquefaction.

Beef-infusion agar colonies: Small, circular, raised, edges smooth, glistening, translucent, bluish-white, amorphous, margin entire.

Agar stab: Abundant growth. Surface growth round, smooth, glistening, bluish-white, raised. Filiform growth the whole length of stab, but growth best at top.

Agar slant: Abundant filiform growth, raised, glistening, smooth, translucent, bluish-white, no odor; old cultures slightly viscid. Medium unchanged.

Nutrient broth: Turbid. Delicate white pellicle. Sediment abundant, white, slightly stringy. No odor. Color of medium unchanged.

Sterile milk: Slow growth. No peptonization. Coagulation in 12 to 14 days. Milk turns chocolate brown beginning at top.

Litmus milk: Acid with reduction of litmus in 5 days. Coagulation with return of pink color in 12 to 14 days. Browning of medium.

Potato: Abundant growth, grayish-white, glistening, smooth, raised. Medium changed from white to smoke-gray.

Indole not formed.

Nitrites produced from nitrates in 7 days at 26°C.

No H_2S produced.

Ammonia not formed.

Diastatic action weak.

Acid but no gas from glucose, lactose, glycerol and mannitol. Alkaline reaction and no gas from sucrose.

Optimum pH 7.0.

Temperature relations: Optimum 26°C. Good growth up to 31°C. Very slight growth at 37° and at −8°C.

Facultative anaerobe.

Source: Isolated from fresh strawberries from Delaware, Maryland and Virginia.

Habitat: Unknown.

Appendix: Many of the following species were described before Gram and flagella stains had been perfected. Hence it is impossible to identify them definitely as belonging to *Achromobacter*. Comparative study is needed in other cases before the remaining species can be placed in their proper place in the genus.

Achromobacter acidum (Chester) Bergey et al. (Species No. 56 of Conn, Storrs Agr. Exper. Sta., 7th Ann. Rept. for 1894, 1895, 83; *Bacterium acidum* Chester, Man. Determ. Bact., 1901, 146; Bergey et al., Manual, 1st ed., 1923, 151.) From milk. See Manual, 4th ed., 1934, 246 for a description of this organism.

Achromobacter agile (Ampola and Garino) Bergey et al. (*Bacillus denitrificans agilis* Ampola and Garino, Cent.

f. Bakt., II Abt., *2*, 1896, 673; *Bacterium denitrificans agilis* Chester, Ann. Rept. Del. Col. Agr. Exp. Sta., *9*, 1897, 76; *Bacterium agile* H. Jensen, Cent. f. Bakt., II Abt., *4*, 1898, 408; *Bacillus denitrificans* Migula, Syst. d. Bakt., *2*, 1900, 796; not *Bacillus denitrificans* Chester, Man. Determ. Bact., 1901, 274; *Bacillus agilis* Chester, Man. Determ. Bact., 1901, 226; not *Bacillus agilis* Tschistowitsch, Berl. klin. Wchnschr., 1892, 512; Bergey et al., Manual, 1st ed., 1923, 138.) From cow manure. See Manual, 4th ed., 1934, 219 for a description of this organism.

Achromobacter album (Eisenberg) Bergey et al. (*Bacillus albus* Eisenberg, Bakt. Diag., 3 Aufl., 1891, 171; *Bacterium albus* Chester, Ann. Rept. Del. Col. Agr. Exp. Sta., *9*, 1897, 76; Bergey et al., Manual, 1st ed., 1923, 141.) From water. Gibbons (Contrib. to Canadian Biol. and Fish., *8*, No. 22, 1934, 279) reports this species from the slime on cod (*Gadus callarias*). See Manual, 4th ed., 1934, 222 for a description of this organism.

Achromobacter amylovorum (Rubentschick) Bergey et al. (*Urobacterium amylovorum* Rubentschick, Cent. f. Bakt., II Abt., *64*, 1925, 168; *ibid.*, *66*, 1926, 161; Bergey et al., Manual, 3rd ed., 1930, 225.) From sewage slime. See Manual, 5th ed., 1939, 514 for a description of this organism.

Achromobacter anaerobium Shimwell. (Jour. Inst. Brewing, *43*, 1937, 507.) From spoiled beer.

Achromobacter aromafaciens (Chester) Bergey et al. (Species No. 41 of Conn, Storrs Agr. Exper. Sta., 7th Ann. Rept. for 1894, 1895, 57; *Bacterium connii* Migula, Syst. d. Bakt., *2*, 1900, 440; not *Bacterium connii* Chester, Man. Determ. Bact., 1901, 146; *Bacterium aromafaciens* Chester, *loc. cit.*, 148; Bergey et al., Manual, 1st ed., 1923, 151.) From milk sent from Uruguay to Chicago World's Fair. See Manual, 5th ed., 1939, 519 for a description of this organism.

Achromobacter arcticum Rusakowa and Butkewitsch. (Microbiology (Russian), *10*, 1941, 137; abst. in Cent. f. Bakt., II Abt., *105*, 1942, 140.) From sea water (Barents Sea).

Achromobacter candicans (Frankland and Frankland) Bergey et al. (*Bacillus candicans* G. and P. Frankland, Ztschr. f. Hyg., *6*, 1889, 397; *Bacterium candicans* Chester, Ann. Rept. Del. Col. Agr. Exp. Sta., *9*, 1897, 130; Bergey et al., Manual, 1st ed., 1923, 149.) From soil. See Manual, 5th ed., 1939, 520 for a description of this organism.

Achromobacter centropunctatum (Jensen) Bergey et al. (*Bacterium centropunctatus* H. Jensen, Cent. f. Bakt., II Abt., *4*, 1898, 410; *Bacillus centropunctatus* Chester, Man. Determ. Bact., 1901, 225; Bergey et al., Manual, 1st ed., 1923, 139.) From cow manure. See Manual, 4th ed., 1934, 220 for a description of this organism.

Achromobacter coccoideum (Chester) Bergey et al. (Species No. 16 of Conn, Storrs Agr. Exper. Sta., 6th Ann. Rept. for 1893, 1894, 51; *Bacterium coccoideum* Chester, Man. Determ. Bact., 1901, 147; Bergey et al., Manual, 1st ed., 1923, 152.) From ripening cream. See Manual, 5th ed., 1939, 520 for a description of this organism.

Achromobacter connii (Chester) Bergey et al. (Culture No. 55, Conn, Storrs Agr. Exp. Sta., 7th Annual Rept. for 1894, 1895, 83; *Bacterium connii* Chester, Man. Determ. Bact., 1901, 146; Bergey et al., Manual, 1st ed., 1923, 149.) From milk. See Manual, 4th ed., 1934, 243 for a description of this organism.

Achromobacter dendriticum (Lustig) Bergey et al. (*Bacillus dendriticus* Lustig, Diagnostica dei batteri delle acque, Torino, 1890 and Diagnostik der Bakterien des Wassers, 1893, 99; *Bacterium dendriticus* Chester, Ann. Rept. Del. Col. Agr. Exp. Sta., *9*, 1897, 103; Bergey et al., Manual, 2nd ed., 1925, 156.) From water. See Manual, 5th ed., 1939, 504 for a description of this organism.

Achromobacter epsteinii Peshkov. (Peshkov, Jour. of Biology (Russian), *6*, 1937, 1003.) From water of a carp pond near Moscow.

Achromobacter fermentationis (Chester) Bergey et al. (*Bacterium fermentationis* Chester, Del. Agr. Exp. Sta. Rept. 1899, 53; Bergey et al., Manual, 1st ed., 1923, 152.) From soil. See Manual, 4th ed., 1934, 247 for a description of this organism. In Chester, Man. Determ. Bact., 1901, 231 this is listed as a synonym of *Bacillus foetidus-liquefaciens* Tavel, Ueber Aetiol. der Strumitis, Basel, 1892.

Achromobacter filefaciens (Jensen) Bergey et al. (*Bacterium filefaciens* H. Jensen, Cent. f. Bakt., II Abt., *4*, 1898, 401; Bergey et al., Manual, 1st ed., 1923, 153.) From dust. See Manual, 4th ed., 1934, 247 for a description of this organism.

Achromobacter formosum (Ravenel) Bergey et al. (*Bacillus formosus* Ravenel, Memoirs Nat. Acad. Sci., *8*, 1896, 12; not *Bacillus formosus* Bredemann and Heigener, Cent. f. Bakt., II Abt., *93*, 1935, 101; *Bacterium formosus* Chester, Ann. Rept. Del. Col. Agr. Exp. Sta., *9*, 1897, 91; Bergey et al., Manual, 1st ed., 1923, 136.) From soil. Gibbons (Contrib. to Canadian Biol. and Fish., *8*, No. 24, 1934, 308) reports this species from fillets of haddock (*Melanogrammus aeglefinus*). See Manual, 5th ed., 1939, 505 for a description of this organism.

Achromobacter galophilum Bergey et al. (Culture No. 27, Baranik-Pikowsky, Cent. f. Bakt., II Abt., *70*, 1927, 373; Bergey et al., Manual, 3rd ed., 1930, 223.) From sea water. See Manual, 5th ed., 1939, 514 for a description of this organism.

Achromobacter gasoformans (Eisenberg) Bergey et al. (Gasbildner Bacillus, Tils, Zeitschr. f. Hyg., *9*, 1890, 315; *Bacillus gasoformans* Eisenberg, Bakt. Diagnostik, 1891, 107; *Bacterium gasoformans* Chester, Ann. Rept. Del. Col. Agr. Exp. Sta., *9*, 1897, 93; Bergey et al., Manual, 1st ed., 1923, 137.) From water. See Manual, 5th ed., 1939, 503 for a description of this organism. Gas bubbles observed in plain gelatin stab.

Achromobacter geminum (Chester) Bergey et al. (*Bacillus geminus minor* Ravenel, Memoirs Nat. Acad. Sci., *8*, 1896, 28; *Bacterium geminus minor* Chester, Ann. Rept. Del. Col. Agr. Exp. Sta., *9*, 1897, 72; *Bacillus geminus* Chester, Man. Determ. Bact., 1901, 216; Bergey et al., Manual, 1st ed., 1923, 142.) From soil. See Manual, 5th ed., 1939, 508 for a description of this organism.

Achromobacter guttatum (Zimmermann) Bergey et al. (*Bacillus guttatus* Zimmermann, Bakt. unserer Trink- u. Nutzwässer, Chemnitz, *1*, 1890, 56; *Bacterium guttatus* Chester, Ann. Rept. Del. Col. Agr. Exp. Sta., *9*, 1897, 94; Bergey et al., Manual, 1st ed., 1923, 140.) From water. See Manual, 5th ed., 1939, 508 for a description of this organism.

Achromobacter halophilum Bergey et al. (Culture No. 36, Baranik-Pikowsky, Cent. f. Bakt., II Abt., *70*, 1927, 373; Bergey et al., Manual, 3rd ed., 1930, 220.) From sea water. See Manual, 5th ed., 1939, 513 for a description of this organism.

Achromobacter hartlebii (Jensen) Bergey et al. (*Bacterium hartlebii* H. Jensen, Cent. f. Bakt., II Abt., *4*, 1898, 449; *Bacillus hartlebii* Chester, Man. Determ. Bact., 1901, 226; Bergey et al., Manual, 1st ed., 1923, 139.) From soil. See Manual, 4th ed., 1934, 219 for a description of this organism.

Achromobacter hyalinum (Jordan) Bergey et al. (*Bacillus hyalinus* Jordan, Report, Mass. State Bd. of Health, 1890, 835; *Bacterium hyalinus* Chester, Ann. Rept. Del. Col. Agr. Exp. Sta., *9*, 1897, 95; Bergey et al., Manual, 1st ed., 1923, 138.) From sand in a septic tank. See Manual, 4th ed., 1934, 216 for a description of this organism. Also reported by Hatcher (Jour. Elisha Mitchell Sci. Soc.,

55, 1939, 332) from the feces of a cockroach (*Periplaneta americana*). Litmus milk acid and coagulated. Gram-negative.

Achromobacter inunctum (Pohl) Bergey et al. (*Bacillus inunctus* Pohl, Cent. f. Bakt., *11*, 1892, 143; *Bacterium inunctus* Chester, Ann. Rept. Del. Col. Agr. Exp. Sta., *9*, 1897, 94; Bergey et al., Manual, 1st ed., 1923, 141.) From water. See Manual, 4th ed., 1934, 221 for a description of this organism.

Achromobacter lacticum Bergey et al. (Kramer, Die Bakteriologie der Landwirtschaft, *2*, 1892, 24; Bergey et al., Manual, 1st ed., 1923, 152.) From slimy milk. See Manual, 5th ed., 1939, 519 for a description of this organism. This appears to refer to Loeffler's slimy milk bacillus, more correctly known as *Bacterium pituitosum* Migula.

Achromobacter larvae (Stutzer and Wsorow) Bergey et al. (*Enterobacillus larvae* Stutzer and Wsorow, Cent. f. Bakt., II Abt., *71*, 1927, 119; Bergey et al., Manual, 3rd ed., 1930, 227.) From intestinal tract of normal and diseased caterpillars of winterwheat cutworm (*Euxoa segetum*). See Manual, 5th ed., 1939, 541 for a description of this organism.

Achromobacter liquidum (Frankland and Frankland) Bergey et al. (*Bacillus liquidus* G. and P. Frankland, Ztschr. f. Hyg., *6*, 1889, 382; *Bacterium liquidum* Chester, Ann. Rept. Del. Col. Agr. Exp. Sta., *9*, 1897, 137; *Pseudomonas liquida* Chester, Man. Determ. Bact., 1901, 311; Bergey et al., Manual, 1st ed., 1923, 145.) From water. See Manual, 5th ed., 1939, 511 for a description of this organism.

Achromobacter litorale (Russell) Bergey et al. (*Bacillus litoralis* Russell, Ztschr. f. Hyg., *11*, 1891, 199; *Bacterium litoralis* Chester, Ann. Rept. Del. Col. Agr. Exp. Sta., *9*, 1897, 94; *Pseudomonas litoralis* Migula, Syst. d. Bakt., *2*, 1900, 879; Bergey et al., Manual, 1st ed., 1923, 138.) See Manual, 5th ed., 1939, 503 for a description of this organism. From mud bottom, Gulf of Naples.

Achromobacter litorale var. 2, Bois and Roy. (Naturaliste Canadien, *71*, 1945, 259.) From intestine of the codfish (*Gadus callarias L.*).

Achromobacter middletownii (Chester) Bergey et al. (Species No. 53 of Conn, Storrs Agr. Exper. Sta., 7th Ann. Rept. for 1894, 1895, 82; *Bacterium middletownii* Chester, Man. Determ. Bact., 1901, 147; Bergey et al., Manual, 1st ed., 1923, 151.) From milk. See Manual, 4th ed., 1934, 245 for a description of this organism.

Achromobacter mucidus Alford and McCleskey. (Proc. Louisiana Acad. Sci., 7, 1943, 25.) From crab meat having musty odor.

Achromobacter nijibetsui Takeda. (Cent. f. Bakt., II Abt., *94*, 1936, 48.) From fish hatchery water. Not pathogenic to salmon eggs.

Achromobacter nitrovorum (Jensen) Bergey et al. (*Bacterium nitrovorum* H. Jensen, Cent. f. Bakt., II Abt., *4*, 1898, 450; Bergey et al., Manual, 1st ed., 1923, 154.) From horse manure. See Manual, 4th ed., 1934, 248 for a description of this organism.

Achromobacter perolens Turner. (Australian Jour. Exp. Biol. and Med. Sci., *4*, 1927, 57.) From musty eggs.

Achromobacter pestifer (Frankland and Frankland) Bergey et al. (*Bacillus pestifer* G. and P. Frankland, Philosoph. Trans. Roy. Soc., London, B, *178*, 1888, 277; *Bacterium pestifer* Chester, Ann. Rept. Del. Col. Agr. Exp. Sta., *9*, 1897, 96; Bergey et al., Manual, 1st ed., 1923, 140.) From dust. See Manual, 5th ed., 1939, 507 for a description of this organism.

Achromobacter pikowskyi Bergey et al. (Culture No. 25, Baranik-Pikowsky, Cent. f. Bakt., II Abt., *70*, 1927, 373; Bergey et al., Manual, 3rd ed., 1930, 222.) From sea water. See Manual, 5th ed., 1939, 514 for a description of this organism.

Achromobacter pinnatum (Ravenel) Bergey et al. (*Bacillus pinnatus*

Ravenel, Memoirs Nat. Acad. Sci., *8*, 1896, 32; *Bacterium pinnatus* Chester, Ann. Rept. Del. Col. Agr. Exp. Sta., *9*, 1897, 72; Bergey et al., Manual, 1st ed., 1923, 142). From soil. S.e Manual, 4th ed., 1934, 223 for a description of this organism.

Achromobacter ravenelii Bergey et al. (*Bacillus geminus major* Ravenel, Memoirs Nat. Acad. Sci., *8*, 1896, 27; *Bacillus raveneli* Chester, Man. Determ. Bact., 1901, 217; Bergey et al., Manual, 1st ed., 1923, 143.) From soil. Gibbons (Contrib. to Canadian Biol. and Fish., *8*, No. 22, 1934, 279) reports this species from the slime on cod (*Gadus callarias*). See Manual, 4th ed., 1934, 224 for a description of this organism.

Achromobacter refractans (Wright) Bergey et al. (*Bacillus refractans* Wright, Mem. Nat. Acad. Sci., *7*, 1894, 442; *Bacterium refractans* Chester, Ann. Rept. Del. Col. Agr. Exp. Sta., *9*, 1897, 82; Bergey et al., Manual, 1st ed., 1923, 150.) From water. See Manual, 4th ed., 1934, 244 for a description of this organism.

Achromobacter reticulare (Jordan) Bergey et al. (*Bacillus reticularis* Jordan, Rept. Mass. State Bd. of Health, 1890, 834; Bergey et al., Manual, 1st ed., 1923, 144.) From the effluent of a septic tank. See Manual, 5th ed., 1939, 510 for a description of this organism.

Achromobacter rodonatum (Ravenel) Bergey et al. (*Bacillus rodonatus* Ravenel, Memoirs Nat. Acad. Sci., *8*, 1896, 40; *Bacterium rodonatus* Chester, Ann. Rept. Del. Col. Agr. Exp. Sta., *9*, 1897, 83; Bergey et al., Manual, 1st ed., 1923, 150.) From soil. See Manual, 4th ed., 1934, 244 for a description of this organism.

Achromobacter rugosum (Chester) Bergey et al. (Species No. 27, Conn, Storrs Agr. Exp. Sta., 1893, 54; *Bacillus rugosus* Chester, Man. Determ. Bact., 1901, 220; not *Bacterium rugosum* Henrici, Arb. Bakt. Inst. Tech. Hochschule Karlsruhe, *1*, 1894, 43; not *Bacillus rugosus* Wright, Memoirs Nat. Acad. Sci., *7*, 1895, 438; *Bacterium geminus major* Chester, Ann. Rept. Del. Col. Agr. Exp. Sta., *9*, 1897, 73; Bergey et al., Manual, 1st ed., 1923, 143.) From soil. See Manual, 4th ed., 1934, 224 for a description of this organism.

Achromobacter sewerinii Bergey et al. (Kultur No. 3, Sewerin, Cent. f. Bakt., II Abt., *1*, 1895, 162; *Vibrio denitrificans* Sewerin, Cent. f. Bakt., II Abt., *3*, 1897, 517; Bergey et al., Manual, 1st ed., 1923, 140.) From horse manure.

Achromobacter solitarium (Ravenel) Bergey et al. (*Bacillus solitarius* Ravenel, Memoirs Nat. Acad. Sci., *8*, 1896, 29; *Bacterium solitarius* Chester, Ann. Rept. Del. Col. Agr. Exp. Sta., *9*, 1897, 71; Bergey et al., Manual, 1st ed., 1923, 143.) From soil. Gibbons (Contrib. to Canadian Biol. and Fish., *8*, No. 22, 1934, 279) reports this species from the slime on cod (*Gadus callarias*). See Manual, 5th ed., 1939, 509 for a description of this organism.

Achromobacter stutzeri (Lehmann and Neumann) Bergey et al., (*Bacillus denitrificans II*, Burri and Stutzer, Cent. f. Bakt., II Abt., *1*, 1895, 392; *Bacterium stutzeri* Lehmann and Neumann, Bakt. Diag., 1 Aufl., *2*, 1896, 237; *Bacillus nitrogenes* Migula, Syst. d. Bakt., *2*, 1900, 793; *Bacillus stutzeri* Chester, Man. Determ. Bact., 1901, 225; Bergey et al., Manual, 3rd ed., 1930, 207.) From horse manure. See Manual, 4th ed., 1934, 221 for a description of this organism.

Achromobacter tiogense (Wright) Bergey et al. (*Bacillus tiogensis* Wright, Memoirs Nat. Acad. Sci., *7*, 1894, 441; *Bacterium tiogensis* Chester, Ann. Rept. Del. Col. Agr. Exp. Sta., *9*, 1897, 82; Bergey et al., Manual, 1st ed., 1923, 150.) From water. See Manual, 4th ed., 1934, 244 for a description of this organism.

Achromobacter ubiquitum (Jordan) Bergey et al. (*Bacillus ubiquitus* Jordan, Rept. Mass. State Bd. of Health, 1890, 830; *Bacterium ubiquitus* Chester, Ann. Rept. Del. Col. Agr. Exp. Sta., *9*, 1897, 144; Bergey et al., Manual, 1st ed., 1923,

153.) From sewage, water and dust. See Manual, 5th ed., 1939, 517 for a description of this organism.

Achromobacter venenosum (Vaughan) Bergey et al. (*Bacillus venenosus* Vaughan, Amer. Jour. Med. Sci., *104*, 1892, 191; Bergey et al., Manual, 1st ed., 1923, 141.) From water. Gibbons (Contrib. to Canadian Biol. and Fish., *8*, No. 22, 1934, 279) reports this species from the slime on cod (*Gadus callarias*) and the feces of dogfish (*Squalus acanthias*). See Manual, 4th ed., 1934, 222 for a description of this organism.

Achromobacter visco-symbioticum (Buchanan and Hammer) Bergey et al. (*Bacillus visco-symbioticum* Buchanan and Hammer, Iowa Agr. Exp. Sta. Res. Bull. 22, 1915, 261; *Escherichia symbiotica* Bergey et al., Manual, 1st ed., 1923, 202; Bergey et al., 3rd ed., 1930, 209.) From ropy milk. See Manual, 4th ed., 1934, 223 for a description of this organism.

Genus III. **Flavobacterium** *Bergey et al.**

(Bergey et al., Manual, 1st ed., 1923, 97; *Flavobacter* Stewart, Jour. Mar. Biol. Assoc. Un. Kingdom, *13*, 1932, 41.) From Latin *flavus*, yellow and *bacterium*, a small rod.

Rods of medium size forming a yellow to orange pigment on culture media. Motile with peritrichous flagella or non-motile. Generally Gram-negative. Characterized by feeble powers of attacking carbohydrates, occasionally forming acid from hexoses but no gas. Occur in water and soil.

The type species is *Flavobacterium aquatile* (Frankland and Frankland) Bergey et al.

Key to the species of genus **Flavobacterium.**

I. Non-motile, and slow or no liquefaction of gelatin.
- A. Litmus milk unchanged.
  - 1. Nitrites not produced from nitrates.
    - 1. *Flavobacterium aquatile.*

II. Motile with peritrichous flagella.
- A. Gelatin liquefied.
  - 1. Litmus milk unchanged.
    - a. Nitrites produced from nitrates.
      - 2. *Flavobacterium diffusum.*
      - 3. *Flavobacterium okeanokoites.*
      - 4. *Flavobacterium rigense.*
    - aa. Nitrites not produced from nitrates.
      - b. From fresh water.
        - 5. *Flavobacterium devorans.*
      - bb. From sea water.
        - 6. *Flavobacterium marinotypicum.*
        - 7. *Flavobacterium marinovirosum.*
        - 8. *Flavobacterium halohydrum.*
        - 9. *Flavobacterium neptunium.*

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* Partially rearranged before his death by Prof. D. H. Bergey, Philadelphia, Pennsylvania, Sept., 1937; further revision by Prof. Robert S. Breed, New York State Experiment Station, Geneva, New York, June, 1945.

2. Litmus milk alkaline.
   a. Nitrites produced from nitrates.
      10. *Flavobacterium suaveolens.*
      11. *Flavobacterium rhenanus.*
   aa. Nitrites not produced from nitrates.
      12. *Flavobacterium marinum.*
      13. *Flavobacterium harrisonii.*

B. Gelatin not liquefied.
1. Litmus milk unchanged.
   a. Nitrites not produced from nitrates.
      14. *Flavobacterium invisible.*
2. Litmus milk acid.
   a. Nitrites not produced from nitrates.
      15. *Flavobacterium lactis.*

III. Non-motile.

A. Gelatin liquefied.
1. Litmus milk unchanged.
      16. *Flavobacterium sewanense.*
2. Litmus milk reduced.
   a. Nitrites not produced from nitrates.
      17. *Flavobacterium arborescens.*
3' Litmus milk alkaline.
   a. Nitrites produced from nitrates.
      18. *Flavobacterium lutescens.*
      19. *Flavobacterium fucatum.*
4. Litmus milk peptonized.
   a. Nitrites not produced from nitrates.
      20. *Flavobacterium esteroaromaticum.*
5. Litmus milk acid.
   a. Nitrites produced from nitrates.
      21. *Flavobacterium balustinum.*
      22. *Flavobacterium dormitator.*
6. Action on litmus milk not recorded. Rust-colored on blood agar.
      23. *Flavobacterium ferrugineum.*

B. Gelatin not liquefied.
1. Litmus milk unchanged.
   a. Nitrites produced from nitrates.
      24. *Flavobacterium proteus.*
   aa. Nitrites not produced from nitrates.
      25. *Flavobacterium breve.*
      26. *Flavobacterium solare.*

C. Action on gelatin not recorded.
1. Litmus milk unchanged.
   a. Nitrites produced from nitrates.
      27. *Flavobacterium flavotenue.*

1. Flavobacterium aquatile (Frankland and Frankland) Bergey et al. (*Bacillus aquatilis* G. and P. Frankland, Ztschr. f. Hyg., *6*, 1889, 381; *Bacterium aquatilis* Chester, Ann. Rept. Del. Col. Agr. Exp. Sta., *9*, 1897, 96; Bergey et

al., Manual, 1st ed., 1923, 100.) From Latin *aquatilis*, aquatic.

Description taken from Frankland and Frankland and from studies by Dr. E. Windle Taylor, Metropolitan Water Board, London, on freshly isolated cultures.

Rods: 0.5 by 2.5 microns, with rounded ends, occurring singly, in pairs and in chains. Oscillatory movement only; long threads often remaining motionless (Franklands). Gram-negative (Taylor).

Gelatin colonies: Center yellow-brown, with radiate arrangement of bundles of threads. Colorless margin. Very slow liquefaction (none in 6 weeks, Taylor).

Gelatin stab: Yellow surface growth. Slow liquefaction.

Agar slant: Yellow, smooth, glistening limited growth.

Broth: Turbid with whitish sediment. No pellicle.

Litmus milk: Unchanged (Taylor).

Potato: Limited, yellow streak to no growth.

Indole not formed (Taylor).

Nitrites not produced from nitrates.

Aerobic, facultative.

Optimum temperature 25°C.

Distinctive characters: Resembles *Flavobacterium arborescens* microscopically; easily distinguished from this organism by its much slower and limited growth on ordinary gelatin and agar media, the marked difference in the appearance of colonies and the inability of *Flavobacterium aquatile* to produce more than a limited growth on potato.

Source: Isolated from the water of deep wells in the chalk region of Kent, England where it occurred as a practically pure culture. Found abundantly and re-isolated by Taylor, 1941 from the same sources (personal communication).

Habitat: Water.

Note: The peritrichous, nitrate reducing and ammonia producing organism identified by Bergey (*loc. cit.*) in 1923, as *Flavobacterium aquatile* appears to have been something resembling *Flavobacterium diffusum*.

2. **Flavobacterium diffusum** (Frankland and Frankland) Bergey et al. (*Bacillus diffusus* G. and P. Frankland, Ztschr. f. Hyg., *6*, 1889, 396; *Bacterium diffusus* Chester, Ann. Rept. Del. Col. Agr. Exp. Sta., *9*, 1897, 97; Bergey et al., Manual, 1st ed., 1923, 100.) From Latin *diffusus*, spreading out, diffuse.

Description completed from Harrison (Canadian Jour. Res., *1*, 1929, 233) as indicated.

Rods: 0.5 by 1.5 microns, occurring singly and in chains. Motile, possessing peritrichous flagella. Gram-negative (Harrison).

Gelatin colonies: Thin, bluish-green, spreading, later faint yellow.

Gelatin stab: Thin, glistening, yellowish-green surface growth. Slow crateriform liquefaction.

Agar slant: Thin, light yellow, glistening.

Broth: Turbid, with greenish-yellow sediment.

Litmus milk: Unchanged (Harrison).

Potato: Thin, smooth, greenish-yellow, glistening growth.

Indole not formed (Harrison).

Nitrites produced from nitrates (Harrison).

Slight acidity from glucose. No acid from sucrose and lactose (Harrison).

Aerobic, facultative.

Optimum temperature 25° to 30°C.

Source: Originally found in soil. Found also by Tataroff (Die Dorpater Wasserbakterien, Dorpat, 1891, 58) in fresh water and by Harrison (*loc. cit.*) from skin of halibut from both the Atlantic and Pacific shores of Canada.

Habitat: Soil, fresh and sea waters.

3. **Flavobacterium okeanokoites** ZoBell and Upham. (Bull. Scripps Inst. of Oceanography, Univ. Calif., *5*, 1944, 270.) From Greek *Oceanus*, the ocean god, the ocean and *coites*, bed.

Rods: 0.8 to 0.9 by 1.2 to 1.6 microns, with rounded ends, many coccoid, occurring singly and in long chains.

Motile by means of peritrichous flagella. Gram-negative.

All media except the fresh-water broth, litmus milk, and potato were prepared with sea water.

Gelatin colonies: Small, circular, convex, entire, rust or orange colored, digest gelatin.

Gelatin stab: Slow napiform liquefaction, yellow growth.

Agar colonies: 2 mm, circular, entire, smooth, convex.

Agar slant: Moderate, filiform, glistening, butyrous growth with yellow pigment.

Sea-water broth: No pellicle, moderate turbidity, moderate viscid sediment.

Fresh-water broth: Good growth.

Litmus milk: No visible change. Casein is digested.

Potato: No visible growth.

Indole not formed.

Nitrites slowly produced from nitrates.

Does not produce acid or gas from glucose, lactose, maltose, sucrose, glycerol, mannitol, xylose, or salicin.

Starch not hydrolyzed.

Hydrogen sulfide is formed.

Ammonia produced from peptone but not from urea.

Fats not hydrolyzed.

Aerobic, facultative.

Optimum temperature 20° to 25°C.

Source: Marine mud.

Habitat: Sea water.

4. **Flavobacterium rigense** Bergey et al. (*Bacillus brunneus rigensis* Bazarewski, Cent. f. Bakt., II Abt., *15*, 1905, 1; Bergey et al., Manual, 1st ed., 1923, 100.) From Riga, the name of the city where the species was isolated.

Rods: 0.75 by 1.7 to 2.5 microns, occurring singly. Motile, possessing peritrichous flagella. Gram-negative.

Gelatin colonies: Circular, entire to undulate, grayish-white, homogeneous.

Gelatin stab: Smooth, yellowish surface growth. Infundibuliform liquefaction. Brownish-yellow sediment.

Agar slant: Narrow, whitish streak, becoming yellowish-brown, spreading. Pigment is water and alcohol soluble. Insoluble in ether.

Broth: Turbid with pellicle and brownish sediment. Cells capsulated.

Litmus milk: Unchanged.

Potato: Yellow, spreading growth. The growth turns brownish.

Hydrogen sulfide not formed.

Indole not formed.

Nitrites produced from nitrates.

Aerobic, facultative.

Optimum temperature 30°C. Brownish colors develop best at lower temperatures. Orange-yellow colors develop best at 37°C.

Habitat: Soil.

5. **Flavobacterium devorans** (Zimmermann) Bergey et al. (*Bacillus devorans* Zimmermann, Bakt. unserer Trink- u. Nutzwässer, Chemnitz, *1*, 1890, 48; *Bacterium devorans* Chester, Ann. Rept. Del. Col. Agr. Exp. Sta., *9*, 1897, 96; Bergey et al., Manual, 1st ed., 1923, 102.) From Latin *devorans*, devouring.

Characters added to Zimmermann's description by Bergey (*loc. cit.*) from his private notes are indicated. Steinhaus (Jour. Bact., *42*, 1941, 771) apparently found the same organism.

Rods: 0.7 by 0.9 to 1.2 microns, occurring singly, in pairs and chains. Motile (Zimmermann), possessing peritrichous flagella (Bergey). Gram-negative (Zimmermann).

Gelatin colonies: Circular, white, granular to filamentous, becoming yellowish-gray.

Gelatin stab: Slow infundibuliform liquefaction.

Agar slant: Thin, gray, spreading.

Broth: Turbid.

Litmus milk: Unchanged.

Potato: No growth (Zimmermann). Yellowish-gray streak (Bergey).

Indole not formed.

Nitrites not produced from nitrates (Bergey).

Aerobic, facultative.

Optimum temperature 25° to 30°C.

Source: From water at Chemnitz (Zimmermann). From water (Bergey). From alimentary tract of the nine-spotted lady beetle (*Coccinella novemnotata* Habst.) (Steinhaus).

Habitat: Water.

6. **Flavobacterium marinotypicum** ZoBell and Upham. (Bull. Scripps Inst. of Oceanography, Univ. Calif., *5*, 1944, 268.) From Latin *marinus*, of the sea and *typicus*, typical.

Rods: 0.5 to 0.7 by 1.4 to 2.0 microns, occurring almost entirely as single cells. Motile by means of four or more peritrichous flagella. Gram-negative.

All media except the fresh-water broth, litmus milk, and potato were prepared with sea water.

Gelatin colonies: Very minute, yellow, with slow liquefaction.

Gelatin stab: Crateriform liquefaction becoming stratiform. Filiform along line of stab.

Agar colonies: Minute, circular, entire, convex, yellow.

Agar slant: Scanty, filiform, butyrous, shiny growth with yellow pigment.

Sea-water broth: Scanty, yellowish pellicle, heavy turbidity, slight viscid sediment.

Fresh-water broth: Good growth.

Litmus milk: Decolorized, neutral, greenish pellicle, slow peptonization.

Potato: Abundant, shiny, greenish-yellow growth. Potato darkened.

Indole not formed.

Nitrites not produced from nitrates.

Produces acid but no gas from glucose and glycerol. Does not ferment lactose, sucrose, mannitol, xylose, or salicin.

Starch not hydrolyzed.

Hydrogen sulfide is formed.

Ammonia produced from peptone but not from urea.

Fats not hydrolyzed.

Aerobic, facultative.

Optimum temperature 20° to 25°C.

Source: Sea water and marine mud.

Habitat: Sea water.

7. **Flavobacterium marinovirosum** ZoBell and Upham. (Bull. Scripps. Inst. of Oceanography, Univ. Calif., *5*, 1944, 271.) From Latin *marinus*, of the sea, and *virosus*, covered with slimy liquid or ooze.

Rods: 0.7 to 0.8 by 0.8 to 2.8 microns, with rounded ends, occurring singly and in long chains. Motile by means of peritrichous flagella. Gram-negative.

All media except the fresh-water broth, litmus milk, and potato were prepared with sea water.

Gelatin colonies: Small, circular, raised, rust-colored. Slowly digest gelatin.

Gelatin stab: Crateriform liquefaction becoming stratiform. Light orange pigment.

Agar colonies: 1 to 2 mm, circular, convex, entire, smooth.

Agar slant: Moderate, filiform, glistening, mucoid growth with grayish-yellow pigment.

Sea-water broth: Heavy turbidity, no pellicle, abundant viscid sediment.

Fresh-water broth: Good growth.

Litmus milk: No visible change. Casein is digested.

Potato: No visible growth.

Indole not formed.

Nitrites not produced from nitrates.

Does not ferment glycerol, glucose, lactose, maltose, sucrose, mannitol, xylose, or salicin.

Starch not hydrolyzed.

Hydrogen sulfide is formed.

Ammonia produced from peptone but not from urea.

Fats not hydrolyzed.

Aerobic, facultative.

Optimum temperature 20° to 25°C.

Source: Sea water and marine mud.

Habitat: Sea water.

8. **Flavobacterium halohydrium** ZoBell and Upham. (Bull. Scripps Inst. of

Oceanography, Univ. Calif., *5*, 1944, 278.) From Greek *hals*, salt and *hydror*, water.

Short rods: 0.6 by 0.8 to 1.0 microns, occurring singly. Motile by means of many peritrichous flagella. Gram-negative.

All media except the fresh-water broth, litmus milk, and potato were prepared with sea water.

Gelatin colonies: Small, circular, orange.

Gelatin stab: Napiform liquefaction becoming crateriform. Beaded along line of stab.

Agar colonies: 2 mm, pulvinate, circular, entire, smooth.

Agar slant: Moderate, glistening, echinulate, butyrous growth with yellow pigment.

Sea-water broth: Yellow surface ring, heavy turbidity, moderate viscid sediment.

Fresh-water broth: No visible growth.

Litmus milk: No visible change. Casein not digested.

Very poorly tolerant of increases or decreases in salinity.

Potato: No visible growth.

Indole not formed.

Nitrites not produced from nitrates.

Produces acid but no gas from glucose, lactose, maltose, sucrose, and salicin. Does not ferment glycerol, mannitol, or xylose.

Starch is hydrolyzed.

Hydrogen sulfide not formed.

Ammonia produced from peptone but not from urea.

Fats not hydrolyzed.

Aerobic, facultative.

Optimum temperature 20° to 25°C.

Source: Sea water and marine mud.

Habitat: Sea water.

9. **Flavobacterium neptunium** ZoBell and Upham. (Bull. Scripps Inst. of Oceanography, Univ. Calif., *5*, 1944, 278.) From Latin *Neptunius*, god of the sea.

Rods: 0.5 to 0.6 by 1.6 to 4.5 microns, many bent rods, occurring singly and in short chains. Motile by means of long, peritrichous flagella. Gram-negative.

All media except the fresh-water broth, litmus milk, and potato were prepared with sea water.

Gelatin colonies: Small, circular, darker centers, sink in gelatin, faintly yellow.

Gelatin stab: Slow napiform liquefaction. Filiform growth along line of stab.

Agar colonies: 2 mm, circular, smooth, entire, convex, dark centers with buff pigment.

Agar slant: Luxuriant, echinulate, glistening, slightly mucoid growth with buff to yellow pigment. Agar discolored brown.

Sea-water broth: Heavy pellicle, scanty turbidity, scanty sediment.

Fresh-water broth: No visible growth.

Litmus milk: No visible change. Casein not digested.

Potato: No visible growth.

Indole not formed.

Nitrites not produced from nitrates.

Produces acid but no gas from glucose, lactose, maltose, and salicin. Does not ferment glycerol, mannitol, xylose, or sucrose.

Starch is hydrolyzed.

Hydrogen sulfide not formed.

Ammonia produced from peptone but not from urea.

Fats not hydrolyzed.

Aerobic, facultative.

Optimum temperature 20° to 25°C.

Source: Marine bottom deposits.

Habitat: Sea water.

10. **Flavobacterium suaveolens** Soppeland. (Jour. Agr. Res., *28*, 1924, 275.) From Latin *suaveolens*, of a sweet odor.

Rods: 0.6 to 0.8 by 1.0 to 1.2 microns, with rounded ends, occurring singly and in pairs. Motile, with peritrichous flagella. Gram-negative on plain agar. Gram-positive in young culture on milk powder agar.

Gelatin stab: Rapid stratiform liquefaction. Medium becomes brown.

Agar colonies: Small, circular, smooth, yellow, amorphous, undulate margin.

Agar slant: Moderate, flat, glistening, opaque, butyrous, yellow, with aromatic odor.

Broth: Turbid with scanty sediment. Aromatic odor, becoming cheesy.

Litmus milk: Peptonized. Alkaline.

Potato: Abundant, yellow, glistening, becoming brown.

Indole formed.

Nitrites are produced from nitrates.

Hydrogen sulfide formed.

Slight acid but no gas from glucose, sucrose and glycerol. No acid from lactose.

Starch hydrolyzed.

Blood serum is liquefied.

Aerobic, facultative.

Optimum temperature 25°C.

Source: Dairy wastes.

Habitat: Unknown.

11. **Flavobacterium rhenanus** (Migula) Bergey et al. (Rhine water bacillus of Burri, Frankland and Frankland, Micro-organisms in Water, 1894, 483; *Bacillus rhenanus* Migula, Syst. d. Bakt., *2*, 1900, 713; *Bacillus rheni* Chester, Manual Determ. Bact., 1901, 251; Bergey et al., Manual, 1st ed., 1923, 103.) Named for the Rhine River.

Characters added to Burri's description by Bergey (*loc. cit.*) from his private notes are indicated. Steinhaus (Jour. Bact., *42*, 1941, 771) apparently found the same organism and has added other characters.

Rods: 0.7 by 2.5 to 3.5 microns, with rounded ends, occurring singly and in chains (Burri). Motile, possessing peritrichous flagella (Bergey). Gram-negative (Bergey).

Gelatin colonies: Convex, colorless, transparent, becoming yellowish.

Gelatin stab: Infundibuliform liquefaction.

Agar colonies: Small, smooth, convex, entire.

Glycerol agar slant: Thin, shining, honey-colored. Growth dry and tough.

Broth: Turbid, with orange-colored pellicle and sediment.

Litmus milk: Soft coagulum, becoming slightly alkaline with yellow ring.

Potato: Moist, glistening, thin, flat, orange to rust-colored.

Indole not formed (Bergey).

Nitrites produced from nitrates (Bergey).

Acid from glucose, maltose, and sucrose but not lactose (Steinhaus).

No hydrolysis of starch (Steinhaus).

No H_2S produced (Steinhaus).

Aerobic facultative.

Optimum temperature 30°C.

Source: From Rhine River water (Burri). From water (Bergey). From eggs in ovary of a walking stick (*Diapheromera femorata* Say) (Steinhaus).

Habitat: Presumably widely distributed in nature.

12. **Flavobacterium marinum** Harrison. (Canadian Jour. of Research, *1*, 1929, 234.) From Latin *marinus*, pertaining to the sea.

Rods: 0.8 by 1.2 to 1.3 microns, with rounded ends. Occur singly and in pairs. Motile with 4 to 5 peritrichous flagella. Encapsulated. Gram-variable. Show blue granules in Gram-negative rods.

Gelatin colonies: Circular, iridescent, whitish margin with pale yellow center. Liquefaction.

Gelatin stab: Saccate to stratiform liquefaction.

Agar colonies: Circular, pale yellow, smooth, convex, granular, reticulate edge.

Agar slant: Amber-yellow, slightly raised, spreading, smooth, glistening, transparent.

Ammonium phosphate agar: Scant growth.

Broth: Turbid, sediment.

Litmus milk: Alkaline. Digestion without coagulation. Clear serum.

Potato: Abundant, amber-yellow, becoming dirty yellow, spreading, glistening.

Indole not formed.

Nitrites not produced from nitrates. Trace of ammonia formed.

Faint acidity from glucose. No action on lactose or sucrose.

Loeffler's blood serum not liquefied. Faint yellow spreading growth.

No H_2S formed.

Aerobic, facultative.

Optimum temperature 20° to 25°C.

Source: Isolated from living halibut obtained at 30 to 50 fathoms, Pacific Ocean. Gibbons (Contrib. to Canadian Biol. and Fish., *8*, No. 22, 1934, 279) reports this species as occurring in the slime and feces of cod (*Gadus callarias*), halibut (*Hippoglossus hippoglossus*) and skate (*Raja erinacea*).

Habitat: Skin and feces of fishes.

13. **Flavobacterium harrisonii** Bergey et al. (Variety No. 6, Harrison, Rev. gén. du Lait, *5*, 1905, 129; *Bacillus lactis harrisonii* Conn, Esten and Stocking, Ann. Rept. Storrs Agr. Exp. Sta., 1906, 169; Bergey et al., Manual, 1st ed., 1923, 104.) Named for Prof. F. C. Harrison, the Canadian bacteriologist who first isolated this species.

Rods: 0.25 to 0.75 by 0.3 to 3.5 microns, occurring singly and occasionally in short chains. Motile, possessing peritrichous flagella. Gram-negative.

Gelatin colonies: Small, gray, glistening, lobular, citron-yellow, slimy.

Gelatin stab: Villous growth in stab. Slow crateriform to napiform liquefaction.

Agar slant: Luxuriant, viscous, spreading, becoming dirty, to brownish citron-yellow.

Broth: Turbid, with viscid ring and gelatinous sediment, sweetish odor, alkaline.

Litmus milk: Colorless to gray and slimy, becoming yellow, alkaline.

Potato: Luxuriant, yellow, spreading, slimy.

Indole not formed.

Glucose, lactose, maltose and sucrose broth turn alkaline with a disagreeable odor. Reaction of glycerol broth remains neutral.

Aerobic, facultative.

Optimum temperature 25°C.

Source: Slimy milk.

Habitat: Unknown.

14. **Flavobacterium invisibile** (Vaughan) Bergey et al. (*Bacillus invisibilis* Vaughan, American Jour. Med. Sci., *104*, 1892, 191; *Bacterium invisibilis* Chester, Ann. Rept. Del. Col. Agr. Exp. Sta., *9*, 1897, 77; Bergey et al., Manual, 1st ed., 1923, 109.) From Latin *invisibilis*, not visibile.

Rods: 0.6 to 0.7 by 1.2 to 2.0 microns, occurring singly. Motile, possessing peritrichous flagella. Gram-negative.

Gelatin colonies: Pale yellow, burr-like, with irregular margin.

Gelatin stab: Scanty growth on surface. Good growth in stab. No liquefaction.

Agar colonies: White, convex, smooth, serrate.

Agar slant: Limited, thick, white streak.

Broth: Turbid.

Litmus milk: Unchanged.

Potato: No growth.

Indole not formed.

Nitrites not produced from nitrates.

Aerobic, facultative.

Optimum temperature 35°C.

Habitat: Water.

15. **Flavobacterium lactis** Bergey et al. (*Bacillus aromaticus lactis* Grimm, Cent. f. Bakt., II Abt., *8*, 1902, 584; *Bacillus aromaticus* Grimm, *ibid.*, 589; not *Bacillus aromaticus* Pammel, Bull. 21, Iowa Agr. Exp. Sta., 1893, 792; Bergey et al., Manual, 1st ed., 1923, 108.) From Latin *lac*, milk.

Rods: 0.7 to 1.0 by 3.5 to 4.0 microns, occurring singly, in pairs and in chains. Motile, possessing peritrichous flagella. Gram-negative.

Gelatin colonies: Circular, light yellow, slimy. Concentrically ringed, undulate.

Gelatin stab: Slimy surface growth. No liquefaction.

Agar slant: Slimy, yellowish, smooth, moist.

Broth: Turbid, with abundant sediment.

Litmus milk: Slightly acid.

Potato: Thick, slimy, brownish, with yellowish margin.

Indole not formed.

Nitrites not produced from nitrates.

Cultures have pleasant odor.

Aerobic, facultative.

Optimum temperature 25°C.

Source: Isolated from milk.

Habitat: Unknown.

16. **Flavobacterium sewanense** (Kalantarian and Petrossian) Bergey et al. (*Bacterium sewanense* Kalantarian and Petrossian, Cent. f. Bakt., II Abt., *85*, 1932, 431; Bergey et al., Manual, 4th ed., 1934, 160.) From M. L., Sevan, a lake in Armenia.

Straight or curved rods: 1.0 to 2.0 by 4.0 to 5.0 microns on Molisch's agar; on meat extract agar and potato agar they are short or even coccoid. Ends rounded, occurring singly or in pairs. Non-motile. Gram reaction not given. Presumably negative.

Gelatin stab: Slow liquefaction.

Agar colonies: Circular, raised, glistening, dirty white. Deep colonies yellow and lens-shaped.

Agar slant: Abundant, dirty yellow, glistening, raised.

Broth: Turbid with characteristic growth forms. Pellicle formed in old cultures.

Milk: Unchanged.

Potato: Yellow, raised, glistening, with darkening of the medium.

No visible gas produced from carbohydrates.

Crystals of calcium carbonate form in old cultures on $CaCl_2$ and Molisch's agar.

Aerobic, facultative.

Optimum temperature 20°C.

Source: Isolated from pellicle formed on surface of fish infusions in Lake Sevan and tap waters containing 1 per cent $CaCl_2$.

Habitat: Sea water. Thought to produce deposits of $CaCO_3$ in Lake Sevan, S. S. R. Armenia.

17. **Flavobacterium arborescens** (Frankland and Frankland) Bergey et al. (*Bacillus arborescens* Frankland and Frankland, Ztschr. f. Hyg., *6*, 1889, 379; also see Tils, Ztschr. f. Hyg., *9*, 1890, 312; Zimmermann, Bakt. unserer Trink- u. Nutzwässer, *2*, 1894, 20; and Wright, Mem. Nat. Acad. Sci., *7*, 1894, 446, var. a and b; *Bacterium arborescens* Chester, Ann. Rept. Del. Col. Agr. Exp. Sta., *9*, 1897, 106; Migula, Syst. d. Bakt., *2*, 1900, 468 uses *Bacillus arborescens* in the text by mistake as *Bacterium* is used for other species in the genus and *Bacterium arborescens* is used in the index, p. 1058; not *Bacillus arborescens* Chester, Man. Determ. Bact., 1901, 249; *Erythrobacillus arborescens* Holland, Jour. Bact., *5*, 1920, 217; Bergey et al., Manual, 1st ed., 1923, 113.) From Latin *arborescens*, becoming a tree or tree-like.

Rods: 0.5 by 2.5 microns, occurring singly and in chains. Non-motile (Franklands). Gram-negative (Zimmermann).

Gelatin colonies: Radiate branching filaments. Center yellowish, border translucent.

Gelatin stab: Liquefied with yellow deposit.

Agar slant: Dirty orange growth.

Broth: Turbid, with orange sediment. No pellicle.

Litmus milk: Slow coagulation; litmus reduced. Reaction unchanged (Wright).

Potato: Deep orange, luxuriant growth.

Nitrites not produced from nitrates.

Aerobic, facultative.

Optimum temperature 30°C.

May belong to *Corynebacterium* (Lehmann and Neumann, Bakt. Diag., 7 Aufl. *2*, 1927, 709).

Source: From river and lake water.

Habitat: Water.

17a. *Bacillus arborescens* Chester. (*Bacillus arborescens non-liquefaciens* Ravenel, Mem. Nat. Acad. Sci., *8*, 1896,

39; *Bacterium arborescens non-liquefaciens* Chester, Ann. Rept. Del. Col. Agr. Exp. Sta., *9*, 1897, 103; not *Bacterium arborescens non-liquefaciens* von Rigler, Hyg. Rund., *12*, 1902, 479; Chester, Man. Determ. Bact., 1901, 249.) Regarded by author as a non-liquefying strain of *Bacillus arborescens* Frankland and Frankland. Not a yellow chromogen. From soil.

18. **Flavobacterium lutescens** (Migula) Bergey et al. (Der gelbe Bacillus, Lustig, Diagnostik der Bakterien des Wassers, 1893, 78; *Bacterium lutescens* Migula, Syst. d. Bakt., *2*, 1900, 476; Bergey et al., Manual, 1st ed., 1923, 114.) From Latin *lutum*, yellow; *lutescens*, becoming yellowish.

Rods: 0.5 by 0.95 micron, occurring singly and in pairs. Non-motile. Gram-negative.

Gelatin colonies: Circular, yellow, lobate.

Gelatin stab: Slow liquefaction.

Agar slant: Pale yellow, becoming golden yellow.

Broth: Turbid.

Litmus milk: Alkaline.

Potato: Luxuriant, golden-yellow growth.

Indole not formed.

Nitrites produced from nitrates.

Aerobic, facultative.

Optimum temperature 30° to 35°C.

Source: From water. Gibbons (Contrib. to Canadian Biol. and Fish., *8*, No. 22, 1934, 279) reports this species as occurring in the slime of the cod (*Gadus callarias*).

Habitat: Fresh and salt water.

19. **Flavobacterium fucatum** Harrison. (Canadian Jour. of Research, *1*, 1929, 232.) From Latin *fucatus*, painted, colored.

Rods: 0.8 to 1.0 by 2.5 to 3.5 microns, slightly bent, with rounded ends. Granular with diphtheroid forms at 37°C. Non-motile. Gram-negative.

Gelatin colonies: Circular, yellow, entire, paler at edges.

Gelatin stab: Crateriform liquefaction.

Agar colonies: Circular, buff-yellow, smooth, shiny, convex to pulvinate, granular, entire.

Agar slant: Moderate, light buff-yellow, spreading, shiny, smooth.

Ammonium phosphate agar: Good growth in 6 days.

Broth: Turbid, becoming clear, pellicle and yellow sediment.

Litmus milk: Alkaline. Peptonized. Clear serum. Yellow sediment.

Potato: Abundant, pale buff-yellow, smooth, spreading, becoming orange-yellow.

Indole not formed.

Nitrites produced from nitrates.

Traces of ammonia formed.

No acid from glucose, lactose or sucrose.

Loeffler's blood serum not liquefied. Light buff-yellow growth becoming ochraceus salmon.

No H_2S formed.

Aerobic, facultative.

Optimum temperature 20° to 25°C.

Source: Repeatedly isolated from living halibut obtained at 30 to 50 fathoms, Pacific Ocean. Also isolated by Gibbons (Contrib. to Canadian Biol. and Fish., *8*, No. 22, 1934, 279) from cod (*Gadus callarias*) and dogfish (*Squalus acanthias*).

Habitat: Skin of fishes.

20. **Flavobacterium esteroaromaticum** (Omelianski) Bergey et al. (*Bacterium esteroaromaticum* Omelianski, Jour. Bact., *8*, 1923, 407; Bergey et al., Manual, 3rd ed., 1930, 149.) From M. L., ester and Greek *aromaticus*, aromatic.

Rods: 0.5 by 1.0 to 3.0 microns. Non-motile. Gram reaction not recorded.

Gelatin stab: Crateriform liquefaction with odor of musk melons.

Agar colonies: Circular, yellow-brown, with fimbriate margin and a fruity aroma.

Broth: Turbid, slight sediment. Faint fruity aroma.

Litmus milk: Peptonized. Cheesy odor.

Potato: Abundant growth. Disagreeable odor.

Loeffler's blood serum: Liquefied.

Indole not formed.

Nitrites not produced from nitrates.

Ammonia formed.

Hydrogen sulfide formed.

Fat hydrolyzed.

Methylene blue reduced.

No acid from carbohydrates.

Aerobic, facultative.

Optimum temperature 30°C.

Source: Accidental contaminant in rabbit brain containing rabies virus.

Habitat: Presumably widely distributed.

21. **Flavobacterium balustinum** Harrison. (Canadian Jour. Research, *1*, 1929, 234.)

Rods: 0.6 by 2.0 to 4.0 microns, forming short chains. Non-motile. Gram-negative.

Gelatin colonies: Circular, bright yellow center, entire.

Gelatin stab: Liquefied.

Agar colonies: Punctiform, cadmium-yellow, convex, shiny, transparent.

Agar slant: Egg yolk-yellow, semi-transparent streak, smooth, shiny, becoming brownish-yellow.

Ammonium phosphate agar: Slight yellow growth.

Broth: Turbid, with yellow sediment.

Litmus milk: Slightly acid with yellow sediment.

Potato: Scant, yellow growth.

Indole not formed.

Nitrites (trace) produced from nitrates. Ammonia not formed.

Faint acidity from glucose. No action on lactose or sucrose.

Loeffler's blood serum not liquefied. Egg yolk-like growth.

No H_2S formed.

Aerobic, facultative.

Optimum temperature 20° to 25°C.

Source: Isolated from living halibut obtained at 30 to 50 fathoms, Pacific Ocean.

Habitat: Skin of fishes.

22. **Flavobacterium dormitator** (Wright) Bergey et al. (*Bacillus dormitator* Wright, Memoirs Nat. Acad. Sci., *7*, 1895, 442; *Bacterium dormitator* Chester, Ann. Rept. Del. Agr. Exp. Sta., *9*, 1897, 109; Bergey et al., Manual, 1st ed., 1923, 115.) From Latin *dormitator*, one who sleeps.

Description completed from Harrison (Canadian Jour. Res., *1*, 1929, 233) whose cultures differed in some particulars from Wright's.

Rods with conical ends, occurring singly, in pairs and in chains. Non-motile. Gram-negative (Harrison).

Gelatin colonies: Small, yellow, slightly granular, liquefying.

Gelatin stab: Infundibuliform liquefaction, yellow sediment.

Agar slant: Yellow, glistening, translucent.

Ammonium phosphate agar: Slight yellow growth.

Broth: Turbid, with slight pellicle and yellow sediment.

Litmus milk: Slightly acid; litmus reduced. Harrison reports no reduction.

Potato: Slight, transparent, yellow growth.

Indole not formed (Harrison).

Nitrite (trace) produced from nitrates (Harrison).

Acid from glucose, sucrose, glycerol and mannitol. No acid from lactose, raffinose, and inulin (Harrison).

Aerobic, facultative.

Optimum temperature 30°C.

Source: Originally isolated from fresh water at Philadelphia. Later isolated by Harrison (*loc. cit.*) from skin of halibut taken in Pacific ocean off Canada. Gibbons (Contrib. to Canadian Biol. and Fish., *8*, No. 22, 1934, 279) reports this

species as occurring in the slime of a haddock (*Melanogrammus aeglefinus*).

Habitat: Fresh and salt water.

23. **Flavobacterium ferrugineum** Sickles and Shaw. (Jour. Bact., *28*, 1934, 421.) From Latin *ferrugineus*, resembling rust.

Small, slender rods: Less than 0.5 by 0.7 to 1.0 micron, occurring singly and in pairs. Non-motile. Gram-negative.

Gelatin: Liquefaction in one week at 37°C; at room temperature liquefaction slower, napiform; yellow sediment along line of puncture.

Blood agar colonies: Dull, rust-colored, 1 mm in diameter, round, entire, umbilicate, rather dry.

Agar colonies: Similar to blood agar colonies but yellowish-gray in color.

Blood agar slants: Moderate growth, rust-colored, rather dry.

Agar slants: Growth very slight, thin, yellowish-gray.

Beef-infusion broth: No growth.

Beef extract broth: Moderate even turbidity. Adding type-specific carbohydrate results in a heavier growth with yellow sediment.

Potato: Moderate growth, bright orange in color. Potato darkened.

Very active hydrolysis of starch.

Acid but no gas from glucose, lactose, sucrose, maltose, dextrin and inulin; very slight action on mannitol; no action on salicin.

Limits of growth: Optimum pH 7.0 to 7.5. Minimum 6.5. Maximum 9.0.

Temperature relations: Optimum 35° to 37°C. Minimum 22°C. Maximum 39°C. Thermal death point 52°C for 10 minutes. Enzyme produced by strain against pneumococcus carbohydrate withstands 56°C for 10 minutes.

Facultative aerobe.

Distinctive character: Decomposes the non-type-specific carbohydrate obtained from a degraded type I pneumococcus.

Source: Several strains isolated from swamps and other uncultivated soils.

Habitat: Soil.

24. **Flavobacterium proteus** Shimwell and Grimes. (Bacterium Y, Shimwell and Grimes, Jour. Inst. Brewing, *42*, N.S. *23*, 1936, 119; Shimwell and Grimes, *ibid.*, 348.) From Latin *Proteus*, a sea god who often changed in form.

Rods: 0.8 to 1.2 by 1.5 to 4.0 microns, occurring singly or in chains, and having rounded ends. Highly pleomorphic. Thickened filaments and spindle-shaped swellings common. Probably non-motile. Gram-negative.

Wort-gelatin plate: Surface colonies irregular, up to 1 mm in diameter, grayish-white or yellowish, flat or slightly raised, margin entire to lobate or crenate. Deep colonies circular, small, yellowish.

Wort-gelatin streak: Scanty, filiform or beaded, slightly raised, at first almost transparent, later more opaque and whitish-buff.

Wort-gelatin stab: Scanty, filiform or beaded, almost colorless. No liquefaction.

Wort-agar plate: Colonies small, pale, buff-colored, resembling bread-crumbs in shape.

Wort-agar streak: Similar to wort-gelatin streak. Sometimes a slight metallic sheen on old cultures.

Broth: Turbid in 24 hours at 30°C, with a slight surface scum.

Litmus milk: Unchanged.

Potato: A slight, barely visible growth consisting of a narrow filiform dirty yellow line.

Indole not produced.

Nitrites are produced from nitrates.

Acetymethylcarbinol not produced.

Starch not hydrolyzed.

Small amount of acid and gas from glucose and maltose. Trace of acid but no gas from sucrose. No acid or gas from lactose.

Acid, gas and ethyl alcohol produced in small quantity from wort together with a pronounced parsnip-like odor.

Optimum pH 5.0. No growth at pH 4.0.

Temperature relations: Optimum 32°C.

Good growth at 18° C. Thermal death point 54° C for five minutes.

Aerobic, facultative.

Distinctive character: Extreme pleomorphism in media of neutral or slightly alkaline reaction.

Source: Isolated from brewers' yeast.

Habitat: The common short rod bacterium of brewers' yeast.

25. **Flavobacterium breve** (Frankland and Frankland) Bergey et al. (Kurzer Canalbacillus, Mori, Ztschr. f. Hyg., *4*, 1888, 53; *Bacillus brevis* G. and P. Frankland, Microorganisms in Water, 1894, 429; not *Bacillus brevis* Migula, Syst. d. Bakt., *2*, 1900, 583; *Bacterium breve* Chester, Man. Determ. Bact., 1901, 172; Bergey et al., Manual, 1st ed., 1923, 116.) From Latin *brevis*, short.

Rods: 0.8 to 1.0 by 2.5 microns, showing polar staining. Non-motile. Gram-negative.

Gelatin colonies: Minute, pale yellow, compact growth in 2 to 3 weeks.

Gelatin stab: Thin, yellowish growth on surface. Beaded growth in stab. No liquefaction.

Agar slant: Yellowish growth in 2 to 3 days.

Broth: Turbid with white sediment.

Blood serum: Growth of light gray color in 2 to 3 days.

Litmus milk: Unchanged.

Potato: No growth.

Aerobic, facultative.

Optimum temperature 35°C.

Habitat: Water.

26. **Flavobacterium solare** (Lehmann and Neumann) Bergey et al. (*Bacterium solare* Lehmann and Neumann, Bakt. Diag., 1 Aufl., *2*, 1896, 258; Bergey et al., Manual, 1st ed., 1923, 116.) From Latin *solaris*, solar.

Rods: 0.3 to 0.4 by 1.0 micron, occurring singly, in pairs and in chains. Non-motile. Gram-negative.

Gelatin colonies: Circular, yellow, glistening, translucent. Projecting rays.

Gelatin stab: Yellow, arborescent growth in stab. No liquefaction.

Agar slant: Pale yellow, raised, arborescent.

Broth: Clear.

Litmus milk: Unchanged.

Potato: Soft, yellowish-brown streak.

Indole not formed.

Nitrites not produced from nitrates.

Aerobic, facultative.

Optimum temperature 30°C.

Distinctive character: Resembles *Flavobacterium arborescens* in type of growth.

Source: Würzburg tap water. Gibbons (Contrib. to Canadian Biol. and Fish., *8*, No. 22, 1934, 279) reports this species as occurring in the slime of a skate (*Raja erinacea*) and of a hake (*Urophycis tenuis*).

Habitat: Fresh and salt water.

27. **Flavobacterium flavotenue** Schrire. (Trans. Royal Soc. South Africa, *17*, 1928, 45.) From Latin *flavus*, tawny yellow and *tenuis*, slender. Probably intended to mean, yellow and slender.

Small rods: Non-motile. Gram-negative.

Agar colonies: Small, circular, lemon yellow, raised, entire.

Agar slant: Filiform, lemon yellow.

Broth: Turbid.

Litmus milk: Unchanged.

Potato: Moist, yellow streak.

Indole not formed.

Nitrites are produced from nitrates.

Acid from glucose, galactose and xylose.

Pathogenic to white mice and guinea pigs.

Aerobic, facultative.

Optimum temperature 20°C.

Source: Isolated from a mold-like growth in a frog (*Xenopus laevis*).

Habitat: Unknown.

Appendix: Some of the following species were described before Gram and flagella stains had been perfected.

Hence it is impossible to identify them definitely as belonging in *Flavobacterium*. Comparative study is needed in some cases before other species listed here can be placed in their proper place in the genus.

Flavobacterium acidificum Steinhaus. (Jour. Bact., *42*, 1941, 772.) From the intestine of the grasshopper (*Conocephalus fasciatus* De G.), the Colorado potato beetle (*Leptinotarsa decemlineata* Say), several unidentified lady beetle larvae, and the white cabbage butterfly (*Pieris rapae L.*).

Flavobacterium antenniforme (Ravenel) Bergey et al. (*Bacillus antenniformis* Ravenel, Memoirs Nat. Acad. Sci., *8*, 1896, 25; *Bacterium antenniformis* Chester, Ann. Rept. Del. Col. Agr. Exp. Sta., *9*, 1897, 91; Bergey et al., Manual, 1st ed., 1923, 104.) From soil. See Manual, 5th ed., 1939, 531 for a description of this organism.

Flavobacterium aurantiacum (Frankland and Frankland) Bergey et al. (*Bacillus aurantiacus* G. and P. Frankland, Zeitschr. f. Hyg., *6*, 1889, 390; *Bacterium aurantiacus* Chester, Ann. Rept. Del. Col. Agr. Exp. Sta., *9*, 1897, 109; Bergey et al., Manual, 1st ed., 1923, 107; *Chromobacterium aurantiacum* Topley and Wilson, Princ. Bact. and Immun., *1*, 1931, 405.) From water. See Manual, 5th ed., 1939, 533 for a description of this organism.

Flavobacterium aurantinum (Hammer) Bergey et al. (*Bacillus aurantinus* Hammer, Research Bull. No. 20, Iowa Exp. Sta., 1915, 149; Bergey et al., Manual, 1st ed., 1923, 107.) From milk. See Manual, 5th ed., 1939, 541 for a description of this organism.

Flavobacterium aurescens (Ravenel) Bergey et al. (*Bacillus aurescens* Ravenel, Memoirs Nat. Acad. Sci., *8*, 1896, 8; not *Bacillus aurescens* Frankland and Frankland, Philo. Trans. Roy. Soc. London, B, 1878, 271; *Bacterium aurescens* Chester, Ann. Rept. Del. Col. Agr. Exp. Sta., *9*, 1897, 105; Bergey et al., Manual, 1st ed., 1923, 102.) From soil. Gibbons (Contrib. Canadian Biol. and Fish., *8*, No. 24, 1934, 307) found this species in fillets of haddock (*Melanogrammus aeglefinus*). See Manual, 4th ed., 1934, 142 for a description of this organism.

Flavobacterium brunneum (Copeland) Bergey et al. (*Bacillus brunneus* Copeland, Rept. Filtration Commission, Pittsburgh, 1899, 348; Bergey et al., Manual, 1st ed., 1923, 112.) From water. See Manual, 5th ed., 1939, 541 for a description of this organism. This may be *Bacillus brunneus* Schroeter, but not *Bacillus brunneus* Eisenberg. The latter forms spores.

Flavobacterium buccalis (Chester) Bergey et al. (Bacillus g, Vignal, Arch. d. phys. norm. et path., Sér. 3, *8*, 1886, 365; *Bacillus buccalis minutus* Sternberg, Manual of Bact., 1893, 643; *Bacterium buccalis minutus* Chester, Ann. Rept. Del. Col. Agr. Expt. Sta., *9*, 1897, 108; *Bacterium vignali* Migula, Syst. d. Bakt., *2*, 1900, 443; *Bacterium bucallis* (sic) Chester, Man. Determ. Bact., 1901, 167; not *Bacterium buccale* Migula, Syst. d. Bakt., *2*, 1900, 445; *Bacillus vignalis* Nepveux, Thèse Fac. Pharm., Paris and Nancy, 1920, 112; Bergey et al., Manual, 1st ed., 1923, 113.) From saliva. See Manual, 5th ed., 1939, 541 for a description of this organism.

Flavobacterium butyri Bergey et al. (*Bacillus aromaticus butyri* Severin, Cent. f. Bakt., II Abt., *11*, 1903, 264; Bergey et al., Manual, 1st ed., 1923, 106.) From sour cream. Produces an agreeable odor. See Manual, 5th ed., 1939, 534 for a description of this organism.

Flavobacterium chlorum Steinhaus. (Jour. Bact., *42*, 1941, 772.) From the intestine of the nine-spotted lady beetle (*Coccinella novemnotata* Habst.).

Flavobacterium denitrificans (Lehmann and Neumann) Bergey et al. (*Bacillus denitrificans I*, Burri and Stutzer, Cent. f. Bakt., II Abt., *1*, 1895, 360; *Bacterium denitrificans I*, Chester, Ann. Rept. Del. Col. Agr. Exp. Sta., *9*, 1897, 77; *Bacterium denitrificans* Lehmann and Neu-

mann, Bakt. Diag., 2 Aufl., *2*, 1899, 273; *Pseudomonas stutzeri* Migula, Syst. d. Bakt., *2*, 1900, 929; *Bacillus denitrificans* Chester, Man. Determ. Bact., 1901, 224; Bergey et al., Manual, 1st ed., 1923, 109; *Chromobacterium denitrificans* Topley and Wilson, Princ. Bact. and Immun., *1*, 1931, 405.) From horse manure. See Manual, 5th ed., 1939, 534 for a description of this organism.

Flavobacterium desidiosum (Wright) Bergey et al. (*Bacillus decidiosus* (sic) Wright, Memoirs Nat. Acad. Sci., *7*, 1895, 443; not *Bacillus desiduosus* McBeth, Soil Sci., *1*, 1916, 450; *Bacterium desidiosus* and *Bacterium decidiosus* Chester, Ann. Rept. Del. Col. Agr. Exp. Sta., *9*, 1897, 107 and 133; *Flavobacterium deciduosum* Bergey et al., Manual, 1st ed., 1923, 114.) From water. Gibbons (Contrib. Canadian Biol. and Fish., *8*, No. 24, 1934, 308) found this species in fillets of haddock (*Melanogrammus aeglefinus*). See Manual, 5th ed., 1939, 544 for a description of this organism.

Flabobacterium flavescens (Pohl) Bergey et al. (*Bacillus flavescens* Pohl, Cent. f. Bakt., *11*, 1892, 144; Bergey et al., Manual, 1st ed., 1923, 107.) From water. See Manual, 5th ed., 1939, 535 for a description of this organism.

Flavobacterium flavum (Fuhrmann) Bergey et al. (*Bacillus flavus* Fuhrmann, Cent. f. Bakt., II Abt., *19*, 1907, 117; Manual, 1st ed., 1923, 101.) From beer. See Manual, 4th ed., 1934, 141 for a description of this organism.

Flavobacterium gelatinum Sanborn. (Jour. Bact., *19*, 1930, 376.) From sea water.

Flavobacterium halmephilum Elazari-Volcani. (Studies on the microflora of the Dead Sea, Thesis, Hebrew Univ., Jerusalem, 1940, VIII and 85.) From the Dead Sea. A yellow halophilic species.

Flavobacterium halophilum Bergey et al. (Culture No. 30 of Baranik-Pikowsky, Cent. f. Bakt., II Abt., *70*, 1927, 373; Bergey et al., Manual, 3rd ed., 1930, 147.) From sea water. See Manual, 5th ed., 1939, 540 for a description of this organism.

Flavobacterium lacunatum (Wright) Bergey et al. (*Bacillus lacunatus* Wright, Memoirs Nat. Acad. Sci., *7*, 1895, 435; *Bacterium lacunatus* Chester, Ann. Rept. Del. Col. Agr. Exp. Sta., *9*, 1897, 110; Bergey et al., Manual, 1st ed., 1923, 117.) From water. See Manual, 5th ed., 1939, 552 for a description of this organism.

Flavobacterium matzoonii (Chester) Bergey et al. (Species No. 46 of Conn, Storrs Agr. Exper. Sta., 7th Ann. Rept. for 1894, 1895, 80; *Bacillus matazooni* (sic) Chester, Man. Determ. Bact., 1901, 236; Bergey et al., Manual, 1st ed., 1923, 107.) From matzoon, a fermented milk from Armenia. See Manual, 5th ed., 1939, 536 for a description of this organism.

Flavobacterium ovale (Wright) Bergey et al. (*Bacillus ovalis* Wright, Memoirs Nat. Acad. Sci., *7*, 1895, 435; *Bacterium ovalis* Chester, Ann. Rept. Del. Col. Agr. Exp. Sta., *9*, 1897, 111; not *Bacterium ovale* Migula, Syst. d. Bakt., *2*, 1900, 458; Bergey et al., Manual, 1st ed., 1923, 117.) From water. See Manual, 5th ed., 1939, 551 for a description of this organism.

Flavobacterium plicatum (Zimmermann) Bergey et al. (*Bacillus plicatus* Zimmermann, Bakt. unserer Trink- u. Nutzwässer, Chemnitz, *1*, 1890, 54; not *Bacillus plicatus* Frankland and Frankland, Phil. Trans. Roy. Soc. London, *178*, B, 1887, 273; Bergey et al., Manual, 1st ed., 1923, 105.) From water. Gram-negative. Non-motile. See Manual, 5th ed., 1939, 532 for a description of this organism. See p. 684.

Flavobacterium pruneaeum Sanborn. (Jour. Bact., *19*, 1930, 376.) From sea water.

Flavobacterium radiatum (Zimmermann) Bergey et al. (*Bacillus radiatus* Zimmermann, Bakt. unserer Trink- u. Nutzwässer, Chemnitz, *1*, 1890, 58; *Bacillus radiatus aquatilis* Frankland and Frankland, Microorg. in Water,

London, 1894, 458; Bergey et al., Manual, 1st ed., 1923, 104.) From water. See Manual, 5th ed., 1939, 531 for a description of this organism. Gram-variable. Slight motility of shorter rods.

Flavobacterium schirokikhii (H. Jensen) Bergey et al. (Salpeter zerstörenden Bacillus, Schirokikh, Cent. f. Bakt., II Abt., *2*, 1896, 205; *Bacterium schirokikhi* H. Jensen, *ibid.*, *4*, 1898, 409; *Bacillus denitrificans* Chester, Man. Determ. Bact., 1901, 274; Bergey et al., Manual, 1st ed., 1923, 100). From horse manure. See Manual, 5th ed., 1939, 527 for a description of this organism.

Flavobacterium stolanatum (Adametz and Wichmann) Bergey et al. (*Bacillus stolonatus* Adametz and Wichmann, Mitt. Oest. Versuchsstat. f. Brauerei u. Mälz., Wien, Heft 1, 1888, 884; *Bacterium stolonatus* Chester, Ann. Rept. Del. Col. Agr. Exp. Sta., *9*, 1897, 76; Bergey et al., Manual, 1st ed., 1923, 106.) See Manual, 5th ed., 1939, 535 for a description of this organism. From water.

Flavobacterium tremelloides (Tils) Bergey et al. (*Bacillus tremelloides* Tils, Ztschr. f. Hyg., *9*, 1890, 292; *Bacterium tremelloides* Chester, Ann. Rept. Del. Col. Agr. Exp. Sta., *9*, 1897, 105; Bergey et al., Manual, 1st ed., 1923, 105.) From river water at Freiburg. Forms a yellow, slimy milk. See Manual, 5th ed., 1939, 532 for a description of this organism.

Flavobacterium (Halobacterium) marismortui Elazari-Volcani. (Studies on the Microflora of the Dead Sea, Thesis, Hebrew Univ., Jerusalem, 1940, V and 48.) From the Dead Sea. This species and *Flavobacterium (Halobacterium) halobium* and *Flavobacterium (Halobacterium) trapanicum* are placed in a new subgenus of *Flavobacterium* named *Halobacterium*. All produce red pigment. The flagellation of these species was not determined. They may be polar flagellate, see *Pseudomonas salinaria* and *P. cutirubra*.

Flavobacterium (Halobacterium) halobium (Petter) Elazari-Volcani. (Microbe du rouge de morue, Le Dantec, Compt. rend. Soc. Biol., Paris, *58*, 1902, 136; *Bacillus halobius ruber* Klebahn, Mitteil. a. d. Inst. f. allg. Bot. Hamburg, *4*, 1919, 47; *Bacterium halobium* Petter, Over rood en andere bacterien van gesouten visch, Diss., Utrecht, 1932; Elazari-Volcani, Studies on the Microflora of the Dead Sea, Thesis, Hebrew Univ., Jerusalem, 1940, V and 59.) From reddened salted codfish.

Flavobacterium (Halobacterium) trapanicum (Petter) Elazari-Volcani. (*Bacterium trapanicum* Petter, Over rood en andere bacterien van gezouten visch, Diss., Utrecht, 1932; Elazari-Volcani, Studies on the Microflora of the Dead Sea, Thesis, Hebrew Univ. Jerusalem, 1940, V and 59.) From the Dead Sea.

FAMILY X. ENTEROBACTERIACEAE RAHN.

(Cent. f. Bakt., II Abt., *96*, 1937, 280.)

Gram-negative straight rods. Motile with peritrichous flagella, or non-motile. Grow well on artificial media. All species attack glucose forming acid, or acid and visible gas (H_2 present). Characteristically nitrites are produced from nitrates (exceptions in *Erwinia* only). Antigenic composition is best described as a mosaic which results in serological interrelationships among the several genera, even extending to other families. Many animal parasites, and some plant parasites causing blights and soft rots. Frequently occur as saprophytes causing decomposition of plant materials containing carbohydrates.

NOTE: Early attempts to develop a satisfactory basis for the recognition of species among the coliform-dysentery-typhoid group of bacteria are reviewed by Winslow, Kligler and Rothberg (Jour. Bact., *4*, 1919, 429). These were largely based on differences in motility, production of indole, ability to liquefy gelatin, and, more particularly, differences in the ability to ferment carbohydrates, especially such compounds as glucose, lactose, sucrose, dulcitol and salicin. The more recent attempts to express differences in species of coliform bacteria by means of the IMViC reaction are reviewed by Parr (Amer. Jour. Public Health, *26*, 1936, 39; Bact. Rev., *3*, 1939, 1), this cryptic symbol indicating the indole test, methyl red acid determination, acetylmethylcarbinol production (Voges-Proskauer reaction) and the utilization of salts of citric acid. Stuart, Griffin and Baker (Jour. Bact., *36*, 1938, 391) and Griffin and Stuart (Jour. Bact., *40*, 1940, 83) have applied these tests plus cellobiose fermentation to a study of a long series of cultures.

Capsulated types of coliform bacteria are still placed in this edition of the MANUAL in a separate genus, *Klebsiella*, although there is some question about the separation of these from the species in *Escherichia* and *Aerobacter*.

Meanwhile, the Kauffmann and White Antigenic Schema has been successfully applied to the recognition of serological groups and types among salmonellas and related organisms. The groupings recognized are outlined in the Salmonella Subcommittee Reports submitted to the 2nd and 3rd Congresses of Microbiology (Jour. Hyg., *34*, 1934, 333 and Proc. 3rd Internat. Cong. for Microbiology, 1940, 832). The successful use of antigenic structure in this field has stimulated a study of the use of H and O antigens as a means of classifying the coliform group (Stuart, Baker, Zimmerman, Brown and Stone, Jour. Bact., *40*, 1940, 101) but this method of classifying the species of coliform bacteria has not proved particularly helpful as yet.

During this same period there has been an increasing appreciation of the closeness of the relationship between certain common chromogenic bacteria (*Serratia*) and the coliform bacteria (Breed and Breed, Cent. f. Bakt., II Abt., *71*, 1927, 435). Moreover, the close relationship between bacteria producing soft rots of living vegetable and other plant tissue (now included in *Erwinia*) and the coliform bacteria has become more evident in recent studies (Waldee, Iowa State Coll. Jour. Sci., *19*, 1945, 435). Many intermediate types are found in rotting vegetable materials, these rotting types having the ability to attack protopectin (Burkey, Iowa State Coll. Jour Sci., *3*, 1928, 57) but not to cause soft rots of living plant tissue.

Borman, Stuart and Wheeler (Jour. Bact., *48*, 1944, 351) have proposed a rearrangement of the species in the family *Enterobacteriaceae* which combines many forms that have previously been regarded as separate species, or even as belonging in separate genera. Only the future can determine which of all of these views best expresses the relationships of the bacteria belonging in the Family *Enterobacteriaceae*.—The Editors.

Key to the tribes of family **Enterobacteriaceae.**

I. Ferment lactose with the formation of acid and visible gas within 24 hours at 37°C or within 48 hours at 25° to 30°C. Some transitional forms produce acid and gas from lactose slowly.

Tribe I. *Escherichеae,* p. 444.

II. Plant parasites. Ferment lactose with formation of acid, or acid and visible gas. Usually attack middle lamellar substance in plant tissues, causing soft rots.

Tribe II. *Erwineae,* p. 463.

III. Ordinarily chromogenic producing a pink, red or orange-red pigment. Occasionally non-pigmented. Ferment glucose and lactose with formation of acid, or acid and visible gas.

Tribe III. *Serrateae,* p. 479.

IV. Lactose not fermented within 30 days either at 37°C or at 25° to 30°C. Urea decomposed within 48 hours.

Tribe IV. *Proteae,* p. 486.

V. Lactose rarely fermented within 30 days either at 37°C or at 25° to 30°C. Urea not decomposed within 48 hours.

Tribe V. *Salmonelleae,* p. 492.

TRIBE I. ESCHERICHEAE BERGEY, BREED AND MURRAY.

(Preprint, Manual, 5th ed., October, 1938, vi.)

Ferment glucose and lactose with the formation of acid and visible gas within 24 hours at 37°C, or within 48 hours at 25° to 30°C. Some forms produce acid and gas from lactose slowly (occasionally not at all). Do not liquefy gelatin except slowly in *Aerobacter cloacae.*

Key to the genera of tribe **Escherichеae.***

I. Acetylmethylcarbinol not produced. Methyl red test positive. Salts of citric acid may or may not be used as a sole source of carbon.

Genus I. *Escherichia,* p. 444.

II. Acetylmethylcarbinol produced. Methyl red test negative. Salts of citric acid used as sole source of carbon.

Genus II. *Aerobacter,* p. 453.

III. Acetylmethylcarbinol may or may not be produced. Methyl red test variable. Salts of citric acid may or may not be used as sole source of carbon. Gas not as abundant as in previous genera. Capsulated forms from respiratory, intestinal and genito-urinary regions.

Genus III. *Klebsiella,* p. 457.

Genus I. **Escherichia** *Castellani and Chalmers*†.

(Castellani and Chalmers, Manual Trop. Med., 3rd ed., 1919, 941; *Colibacterium* Orla-Jensen, Jour. Bact., *6*, 1921, 272; *Colobactrum* (in part) Borman, Stuart and

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* Levine (Jour. Bact., *1*, 1916, 153) was the first to show the inverse correlation between the methyl red and Voges-Proskauer tests and used these characters for the primary separation of the *Escherichia coli* section and the *Aerobacter aerogenes* section (Amer. Jour. Public Health, 7, 1917, 784).

† Completely revised by Prof. M. W. Yale, New York State Experiment Station, Geneva, New York, Nov., 1938; further revision, July, 1943.

Wheeler, Jour. Bact., *48*, 1944, 357.) Named for Theodor Escherich, who first isolated the type species.

Short rods fermenting glucose and lactose with acid and gas production. Acetylmethylcarbinol is not produced. Methyl red test positive. Carbon dioxide and hydrogen produced in approximately equal volumes from glucose. Generally not able to utilize uric acid as a sole source of nitrogen. Found in feces and is occasionally pathogenic to man (colitis, cystitis, etc.). It is, however, also widely distributed in nature.

The type species is *Escherichia coli* (Migula) Castellani and Chalmers.

Key to the species of genus **Escherichia.**

I. Citric acid and salts of citric acid not utilized as sole source of carbon.
  A. Hydrogen sulfide not produced.
    1. *Escherichia coli.*

II. Citric acid and salts of citric acid utilized as sole source of carbon.
  A. Hydrogen sulfide produced.
    2. *Escherichia freundii.*
  B. Hydrogen sulfide not produced.
    3. *Escherichia intermedium.*

1. **Escherichia coli** (Migula) Castellani and Chalmers. (*Bacterium coli commune* Escherich, Die Darmbakterien des Neugeborenen und Säuglings, 1885; *Bacillus escherichii* Trevisan, I generi e le specie delle Batteriacee, 1889, 15; *Bacillus coli communis* Sternberg, Manual of Bacteriology, 1893, 439; *Bacillus coli* Migula, in Engler and Prantl, Natürlichen Pflanzenfam., *1*, 1a, 1895, 27; *Bacterium coli* Lehmann and Neumann, Bakt. Diag., 1 Aufl., *2*, 1896, 224; *Bacillus coli verus* Durham, Jour. Exp. Med., *5*, 1900, 371; *Bacillus coli communis verus* Durham, *ibid.*, 353; *Aerobacter coli* Beijerinck, Cent. f. Bakt., II Abt., *6*, 1900, 193; Castellani and Chalmers, Man. Trop. Med., 3rd ed., 1919, 941; *Bacillus coli-communis* Winslow, Kligler and Rothberg, Jour. Bact., *4*, 1919, 483; *Bacterium coli-communis* Holland, Jour. Bact., *5*, 1920, 217; *Colobactrum coli* Borman, Stuart and Wheeler, Jour. Bact., *48*, 1944, 358.) From Latin *colon*, the large intestine.

NOTE: Weldin (Iowa State Jour. Sci., *1*, 1927, 121) considers the following identical with the above: *Bacillus cavicida* Flügge, Die Mikroorganismen, 1886, 268 or more probably Brieger, Berlin. klin. Wochnschr., 1884, No. 14; Bacillus C, Booker, Trans. Ninth Internat. Med. Congress, *3*, 1887, 598; *Bacillus schafferi* von Freudenreich, Landw. Jahrb. d. Schweiz, *4*, 1890, 17; *Bacterium cavicida* Chester, Ann. Rept. Del. Col. Agr. Exp. Sta., *9*, 1897, 130; *Bacterium schafferi* Chester, *ibid.*, 74; *Bacillus mustelae septicus* Matzuschita, Bakt. Diag., 1902; *Bacillus communis* Jackson, Jour. Inf. Dis., *8*, 1911, 241; not *Bacillus communis* Migula, Syst. d. Bakt., *2*, 1900, 725; *Escherichia cavicida* Castellani and Chalmers, Manual of Trop. Med., 3rd ed., 1919, 942; *Escherichia schaefferi* Bergey et al., Manual, 1st ed., 1923, 196.

Oesterle (Cent. f. Bakt., I Abt., Orig., *134*, 1935, 115) has described a yellow strain *Bacterium coli flavum*, Parr (Proc. Soc. Exp. Biol. and Med., *35*, 1937, 563) a golden-brown strain *Bacterium aurescens* (not *Bacterium aurescens* Migula, Syst. d. Bakt., *2*, 1900, 466), and Tittsler (Jour. Bact., *33*, 1937, 450) reddish-orange strains which are regarded as pigmented variants of *Escherichia coli.*

Rods: Usually 0.5 by 1.0 to 3.0 microns, varying from almost coccoid forms to long rods, occurring singly, in pairs and short chains. Motile or non-motile. Motile

strains have peritrichous flagella. Not usually capsulated. Non-spore-forming. Gram-negative.

Gelatin colonies: Opaque, moist, grayish-white, entire.

Gelatin stab: Grayish-white, spreading, undulate. No liquefaction.

Agar colonies: Usually white, sometimes yellowish-white, rarely yellow, yellow-brown, golden-brown, reddish-orange or red; entire to undulate, moist, homogeneous. Atypical forms occur frequently.

Agar slant: Usually white, sometimes yellowish-white, rarely yellow, yellow-brown, golden-brown, reddish-orange or red growth; moist, glistening, spreading.

Broth: Turbid, with heavy grayish sediment. No pellicle.

Litmus milk: Rapid acid formation with development of gas, usually coagulation, curd may or may not be broken up, no peptonization of the curd. Litmus may or may not be reduced.

Potato: Abundant, grayish to yellowish-brown, spreading.

Indole usually formed.

Nitrites produced from nitrates.

Blood agar plates: Different strains vary widely in their action, some being hemolytic (Buchgraber and Hilkó, Cent. f. Bakt., I Abt., Orig., *133*, 1935, 449).

Heat resistance: Usually destroyed in 30 minutes at 60°C, but certain heat-resistant strains may withstand this exposure (Ayers and Johnson, Jour. Agr. Res., *3*, 1914, 401; Stark and Patterson, Jour. Dairy Sci., *19*, 1936, 495).

Antigenic structure: An antigenically heterogeneous species.

Methyl red test positive (Clark and Lubs, Jour. Inf. Dis., *17*, 1915, 160); Voges-Proskauer test negative (Durham, Jour. Exp. Med., *5*, 1901, 373); inverse correlation between methyl red and Voges-Proskauer tests (Levine, Jour. Bact., *1*, 1916, 153).

Citric acid and salts of citric acid not utilized as sole source of carbon (Koser, Jour. Bact., *8*, 1923, 493).

Uric acid not utilized as sole source of nitrogen (Koser, Jour. Inf. Dis., *23*, 1918, 377); uracil utilized as sole source of nitrogen (Mitchell and Levine, Jour. Bact., *35*, 1938, 19).

Gas ratio: Approximately equal volumes of carbon dioxide and hydrogen, ratio 1:1, produced from glucose (Harden and Walpole, Proc. Roy. Soc., Ser. B, *77*, 1905, 399; Rogers, Clark and Davis, Jour. Inf. Dis., *14*, 1914, 411).

Catalase produced.

No H_2S produced in peptone iron agar (Levine, Epstein and Vaughn, Amer. Jour. Public Health, *24*, 1934, 505; Tittsler and Sandholzer, Amer. Jour. Public Health, *27*, 1937, 1240). More sensitive indicators give positive tests for H_2S (Hunter and Weiss, Jour. Bact., *35*, 1938, 20).

Trimethyleneglycol not produced from glycerol by anaerobic fermentation (Braak, Onderzoekingen over Vergisting van Glycerine, Thesis, Delft, 1928, 166; Werkman and Gillen, Jour. Bact., *23*, 1932, 167).

Acid and gas from glucose, fructose, galactose, lactose, maltose, arabinose, xylose, rhamnose and mannitol. Sucrose, raffinose, salicin, esculin, dulcitol and glycerol may or may not be fermented. Variable fermentation of sucrose and salicin (Sherman and Wing, Jour. Bact., *33*, 1937, 315; Tregoning and Poe, Jour. Bact., *34*, 1937, 473). Inulin, pectin and adonitol rarely fermented. Dextrin, starch, glycogen and inositol not fermented. Cellobiose (Jones and Wise, Jour. Bact., *11*, 1926, 359) and α-methylglucoside (Koser and Saunders, Jour. Bact., *24*, 1932, 267) not fermented. Certain strains produce variants which ferment lactose slowly or not at all (Rennebaum, Jour. Bact., *30*, 1935, 625). Some strains of slow-lactose-fermenters appear to be intermediate between the coliform and paratyphoid groups (Sandiford, Jour. Path. and Bact., *41*, 1935, 77). See Twort (Proc. Royal Soc. London, *79*, 1907, 329) for utilization of unusual glucosides; Dozois et al. (Jour. Bact., *30*, 1935, 189 and *32*, 1936, 499)

for utilization of certain sugar alcohols and their anhydrides; Poe and Klemme (Jour. Biol. Chem., *109*, 1935, 43) for utilization of rare sugars. See Winslow, Kligler and Rothberg (Jour. Bact., *4*, 1919, 429) for review of literature relative to classification.

Fecal odor produced.

Aerobic, facultative.

Growth requirements: Good growth on ordinary laboratory media. Optimum growth temperature 30° to 37°C. Growth takes place at 10°C and at 45°C. Gas produced from glucose at 45° to 46°C. Eijkmann test positive (Eijkmann, Cent. f. Bakt., I Abt., Orig., *37*, 1904, 74; Perry and Hajna, Jour. Bact., *26*, 1933, 419).

Source: From feces of infants.

Habitat: Normal inhabitant of the intestine of man and all vertebrates. Widely distributed in nature. Frequently causes infections of the genito-urinary tract. Invades the circulation in agonal stages of diseases.

1a. *Escherichia coli* var. *acidilactici* (Topley and Wilson) Yale.

(Milchsaurebacterium, Hueppe, Mit. d. kais. Gesund., *2*, 1884, 340; *Bacillus acidi lactici* Zopf, Die Spaltpilze, 1885, 87; not *Bacterium acidi lactici* Zopf, Die Spaltpilze, 1884, 60; *Bacillus acidi lactici I* and *II* Grotenfelt, Fortschr. d. Med., *7*, 1889, 121; possibly also *Bacterium acidi lactici I* and *II* Grotenfelt, *ibid.*, 123; *Bacterium acidi lactici* Migula, in Engler and Prantl, Natürlichen Pflanzenfamilien, *1*, 1a, 1895, 25; not *Bacterium acidi lactici* Kruse, in Flügge, Die Mikroorganismen, 3 Aufl., *2*, 1896, 357; not Bacterium B, Peters, Bot. Zeitung, *47*, 1889, 422); possibly *Bacterium grotenfeldtii* Migula, Syst. d. Bakt., *2*, 1900, 408, a synonym of *Bacterium acidi lactici* I Grotenfelt; *Bacillus acidilactici* Jackson, Jour. Inf. Dis., *8*, 1911, 241; possibly *Bacillus lacticus* Macé, Traité pratique de bact., 1913, 452; not *Bacillus lacticus* Kruse, in Flügge, Die Mikroorganismen, *2*, 1896, 356; *Bacterium duodenale* Ford, Studies from Victoria Hospital, Montreal, *1*, 1903, 17 (according to Perkins, Jour. Inf. Dis., *37*, 1925, 247); *Encapsulatus acidi lactici* Castellani and Chalmers, Manual of Trop. Med., 1919, 934; *Bacillus lactici-acidi* Holland, Jour. Bact., *5*, 1920, 218; *Bacterium acidi-lactici* Holland, *ibid.*; (*Encapsulata*) *Bacillus duodenale* Perkins, Jour. Inf. Dis., *37*, 1925, 247; *Escherichia acidi-lactici* Bergey et al., Manual, 1st ed., 1923, 199; *Bacterium coli* var. *acidi lactici* Topley and Wilson, Princip. Bact. and Immun., *1*, 1931, 446; Yale, in Manual, 5th ed., 1939, 393.)

Identification: Includes strains of *Escherichia coli* which do not attack either sucrose or salicin. It is generally thought that Hueppe's cultures were contaminated with a spore-former.

Source: From milk.

1b. *Escherichia coli* var. *neapolitana* (Topley and Wilson) Yale. (Neapeler Bacterien, Emmerich, Deut. med. Wehnschr., *10*, 1884, 299; *Bacillus neapolitanus* Flügge, Die Mikroorganismen, 1886, 270; *Bacterium neapolitanus* Chester, Ann. Rept. Del. Col. Agr. Exp. Sta., *9*, 1897, 138; *Escherichia neapolitana* Castellani and Chalmers, Man. Trop. Med., 3rd ed., 1919, 942; *Bacterium coli* var. *neapolitanum* Topley and Wilson, Princip. Bact. and Immun., *1*, 1931, 446; Yale, in Manual, 5th ed., 1939, 393.)

Identification: Includes strains of *Escherichia coli* which ferment sucrose and salicin.

Source: From cholera patients or cadavers, originally thought to be the cause of cholera.

1c. *Escherichia coli* var. *communior* (Topley and Wilson) Yale. (*Bacillus coli communior* Durham, Jour. Exp. Med., *5*, 1900, 353; *Bacillus communior* Ford, Studies from Victoria Hosp., Montreal, *1*, 1903, 17; *Bacterium communior* Jackson, Jour. Inf. Dis., *8*, 1911, 241; *Bacillus coli-communior* Holland, Jour. Bact., *5*, 1920, 217; *Bacterium coli-communior*

Holland, *idem*; *Escherichia communior* Bergey et al., Manual, 1st ed., 1923, 200; *Bacterium coli* var. *communior* Topley and Wilson, Princip. Bact. and Immun., *1*, 1931, 446; Yale, in Manual, 5th ed., 1939, 393.)

Yale (Cornell Vet., *23*, 1933, 306) regards *Bacterium astheniae* Dawson (15th Ann. Rpt., Bur. Anim. Ind., U.S.D.A., 1898, 329; *Bacillus astheniae* Winslow, Kligler and Rothberg, Jour. Bact., *4*, 1919, 487; *Escherichia astheniae* Bergey et al., Manual, 1st ed., 1923, 205) as a synonym of *Escherichia communior*.

Identification: Includes strains of *Escherichia coli* which ferment sucrose but not salicin. Levine (Iowa Eng. Exp. Sta. Bul. 62, 1921, 38) recognizes a strain which ferments salicin.

2. **Escherichia freundii** (Braak) Yale. (*Bacterium freundii* Braak, Onderzoekingen over vergisting van glycerine. Thesis, Delft, 1928, 140; *Citrobacter freundii* Werkman and Gillen, Jour. Bact., *23*, 1932, 176; Yale, in Manual, 5th ed., 1939, 394; *Colobactrum freundii* Borman, Stuart and Wheeler, Jour. Bact., *48*, 1944, 358.) Named for A. Freund, who first observed that trimethyleneglycol was a product of fermentation (1881).

Minkewitsch (Ztschr. f. Hyg., *111*, 1930, 180) proposed the name *Bacterium coli citrovorum* for the intermediates but this name is not acceptable since it is a trinomial.

Werkman and Gillen (Jour. Bact., *23*, 1932, 177) emended the description of *Bacterium freundii*, and created the genus *Citrobacter*. The following species renamed by Werkman and Gillen are regarded as identical with *Escherichia freundii*: *Citrobacter album*, *Citrobacter decolorans*, *Citrobacter diversum* and *Citrobacter anindolicum*.

Tittsler and Sandholzer (Jour. Bact., *29*, 1935, 349) and Carpenter and Fulton (Amer. Jour. Pub. Health, *27*, 1937, 822) suggest that the intermediates which give a positive methyl red and a negative Voges-Proskauer test be allocated to the genus *Escherichia*. Other strains are apparently more nearly related to the genus *Aerobacter* than to the genus *Escherichia* since they produce acetylmethylcarbinol. Barritt (Jour. Path. and Bact., *42*, 1936, 441; *44*, 1937, 679) has shown that some of the intermediates form traces of acetylmethylcarbinol which can be detected by the α-naphthol test, but not by the standard Voges-Proskauer test as described in the Manual of Methods for the Pure Culture Study of Bacteria (Soc. Amer. Bact., 1937, 17).

Rods: Short rods with rounded ends, occurring singly, in pairs and short chains. Motile or non-motile. Gram-negative.

Gelatin stab: Liquefaction by 4 out of 15 cultures (Werkman and Gillen, Jour. Bact., *23*, 1932, 177). No liquefaction by any strains (Tittsler and Sandholzer, Jour. Bact., *29*, 1935, 353; Carpenter and Fulton, Amer. Jour. Pub. Health, *27*, 1937, 822).

Agar slant: Smooth, gray, shining, filiform and butyrous growth.

Litmus milk: Acid in 2 days; coagulation may or may not take place; no peptonization.

Potato: Abundant, yellowish-white growth.

Indole may or may not be formed (Werkman and Gillen, *loc. cit.*; Tittsler and Sandholzer, *loc. cit.*).

Nitrites produced from nitrates.

Methyl red test positive. Voges-Proskauer test negative (Koser, Jour. Bact., *9*, 1924, 59). Some strains give a positive methyl red and a positive Voges-Proskauer test (Parr, Jour. Bact., *36*, 1938, 1).

Citric acid utilized as sole source of carbon; uric acid not utilized as the sole source of nitrogen (Koser, *loc. cit.*; Werkman and Gillen, *loc. cit.*, 167).

Catalase produced.

Hydrogen sulfide produced in proteose peptone, ferric citrate agar (Levine,

Epstein and Vaughn, Amer. Jour. Pub. Health, *24*, 1934, 505; Tittsler and Sandholzer, Amer. Jour. Pub. Health, *27*, 1937, 1240).

Trimethyleneglycol produced from glycerol by anaerobic fermentation (Braak, *loc. cit.*, 146; Werkman and Gillen, *loc. cit.*, 167).

Acid and gas from glucose, fructose, galactose, arabinose, xylose, raffinose, lactose, maltose, mannose, rhamnose, trehalose, glycerol, mannitol and sorbitol. Sucrose, salicin, dulcitol, adonitol and inositol may or may not be fermented. Cellobiose usually fermented while α-methyl-glucoside may or may not be fermented (Tittsler and Sandholzer, *loc. cit.*; Carpenter and Fulton, *loc. cit.*). No acid or gas from amygdalin, dextrin, erythritol, glycogen, inulin or melezitose.

Aerobic, facultative.

Growth requirements: Good growth on ordinary laboratory media. Optimum growth temperature 30° to 37°C. Gas not produced in Eijkman test when carried out at 45° to 46°C (Levine, Epstein and Vaughn, *loc. cit.*). No gas at 44°C (Wilson, Med. Res. Council, London, Special Rept. Ser. 206, 1935, 165).

Habitat: Normally found in soil and water and to a varying degree in the intestinal canal of man and animals. Widely distributed in nature.

3. **Escherichia intermedium** (Werkman and Gillen) Vaughn and Levine. (*Citrobacter intermedium* Werkman and Gillen, Jour. Bact., *23*, 1932, 178; Vaughn and Levine, Jour. Bact., *44*, 1942, 498.)

Citrobacter glycologenes Werkman and Gillen (*loc. cit.*) is also regarded as a synonym of *Escherichia intermedium*. Vaughn and Levine (*loc. cit.*) give a new description of *Escherichia intermedium* based on a study of 27 cultures.

Rods: Short rods with rounded ends. Occurring singly, in pairs and short chains in young nutrient agar or broth cultures. Actively motile with peritrichous flagella or non-motile. Gram-negative.

Gelatin stab: No liquefaction after 60 days at 20°C.

Agar slant: Smooth to wrinkled surface, grayish-white, abundant, raised and butyrous growth.

Nutrient broth: Turbid with slight ring at surface.

Litmus milk: Acid, sometimes coagulation and reduction, no proteolysis.

Potato: Growth abundant, white to ivory color.

Levine's eosine-methylene blue agar: Well-isolated colonies vary from 1 to 4 mm in size. No confluence of neighboring colonies. Colonies are slightly to moderately raised with surfaces varying from flat to convex and usually smooth and glistening but sometimes dull, rough and granular.

By transmitted light two types of colonies have been observed: (1) Colonies having almost the same appearance throughout but with a distinctly lighter center, the color being similar to the medium. (2) Colonies having a dark brownish central area which diffuses out to a lighter margin.

By reflected light three types of colonies have been observed: (1) Dark, button-like, concentrically ringed colonies possessing a strong, greenish-metallic sheen so characteristic for *Escherichia coli*. (2) Colonies with dark, purplish, wine-colored centers surrounded by a light pink zone. Some colonies are concentrically ringed. (3) Pink colonies with no suggestion of sheen but sometimes concentrically ringed.

Indole may or may not be formed.

Nitrites produced from nitrates.

Fermentation of glucose: The end products characteristic for the genus *Escherichia* are formed. Carbon dioxide and hydrogen gases are formed in approximately equimolar proportions (gas ratio 1:1) besides significant quantities of ethyl alcohol, and acetic, lactic and succinic acids with only traces of formic acid. Acetylmethylcarbinol and 2-3

butylene glycol have not been found (Voges-Proskauer test negative).

Salts of citric acid are utilized as a sole source of carbon.

Catalase produced.

Hydrogen sulfide not detected in proteose peptone ferric-citrate agar.

Acid or acid and gas produced from xylose, arabinose, rhamnose, glucose, fructose, mannose, galactose, lactose, maltose, trehalose and mannitol. No acid or gas from melezitose, amygdalin and erythritol. Sucrose, raffinose, cellobiose, α-methyl-glucoside, adonitol, dulcitol, glycerol, inositol, sorbitol, starch, aesculin, salicin and sodium malonate may or may not be fermented.

Aerobic, facultative.

Temperature requirements: Growth at 10°C and at 45° to 46°C. Optimum growth temperature 30° to 37°C. Gas not produced in Eijkman tests, although some cultures show growth at 45° to 46°C.

Salt tolerance: Most cultures ferment glucose in the presence of sodium chloride in a concentration of 6.0 to 7.0 per cent. A few cultures tolerate 8.0 per cent sodium chloride.

pH range: Optimum about pH 7.0. Growth occurs at pH 5.0 to pH 8.0.

Habitat: Normally found to a varying degree in soil, water and in the intestinal canal of man and animals. Widely distributed in nature.

Appendix: The following described species have been placed in *Escherichia* or may belong here:

Bacillus alcalescens Ford. (Ford, Studies from the Royal Victoria Hosp., Montreal, *1*, (5), 1903, 37; also see Jour. Med. Res., *6*, 1901, 211; not *Bacillus alkalescens* Andrews, Lancet, *194*, 1918, 560; *Escherichia alcalescens* Bergey et al., Manual, 1st ed., 1923, 202.) From feces.

Bacillus asiaticus Castellani. (Castellani, Cent. f. Bakt., I Abt., Orig., *65*, 1912, 262; not *Bacillus asiaticus* Sakharoff, Ann. Inst. Past., *8*, 1893, 550; *Salmonella asiaticus* Castellani and Chalmers, Manual of Trop. Med., 3rd ed. 1919, 940; *Proteus asiaticus* Bergey et al Manual, 1st ed., 1923, 211; *Bacterium asiaticum* Weldin and Levine, Abst. Bact., *1*, 1923, 13.) From feces. Ferments lactose slowly or not at all.

Bacillus asiaticus mobilis Castellani. (Valérie 21, Boycott, Jour. Hyg., *6*, 1906, 33; Castellani, Ann. di Med., Nav. e Colon., *11*, 1916, 453; *Salmonella asiaticus mobilis* Castellani and Chalmers, Manual of Trop. Med., 3rd ed., 1919, 940; *Bacterium valeriei* Weldin and Levine, Abst. Bact., *7*, 1923, 13; *Proteus valeriei* Bergey et al., Manual, 1st ed., 1923, 211.) From feces. A motile variety which Alves (Jour. Path. and Bact., *44*, 1937, 485) found to be identical with *Bacillus asiaticus*.

Bacillus chylogenes Ford. (Ford, Studies from the Royal Victoria Hosp., Montreal, *1*, (5), 1903, 62; also see Jour. Med. Res., *6*, 1901, 219.) From feces.

Bacillus coli immobilis Kruse. (Kruse, in Flügge, Die Mikroorganismen, 3 Aufl., *2*, 1896, 339; *Bacterium coli immobilis* Chester, Del. Agr. Exp. Sta., 9th Ann. Rept., 1897, 128; *Enteroides entericus* Castellani, Jour. Hyg., *7*, 1907, 1; *Bacillus schafferi* MacConkey, Jour. Hyg., *9*, 1909, 86; not *Bacillus schafferi* von Freudenreich, Landwirtschl. Jahrb. den Schweiz, *4*, 1890, 17; *Bacillus entericus* Castellani and Chalmers, Manual of Trop. Med., 1st ed., 1910, 990; not *Bacillus entericus* Ford, Studies from Royal Victoria Hosp., Montreal, *1*, (5), 1903, 40; *Escherichia schaefferi* Bergey et al., Manual, 1st ed., 1923, 196; *Bacterium coli* var. *immobilis* Winslow et al., Jour. Bact., *4*, 1919, 486; *Bacterium schafferi* Weldin and Levine, Abst. Bact., *7*, 1923, 13; not *Bacterium schafferi* Chester, Ann. Rept. Del. Col. Agr. Exp. Sta., *9*, 1897, 74; *Escherichia enterica* Weldin, Iowa State Coll. Jour. Sci., *1*, 1927, 134.) From feces. These were all described as non-motile variants of *Escherischia coli* (see Weldin, *loc. cit.*).

Bacillus coli mutabilis Neisser.

(Neisser, Cent. f. Bakt., I Abt., Ref. (Supp.), *38*, 1906, 98; *Bacterium coli mutabile* Massini, Arch. f. Hyg., *61*, 1907, 250; *Escherichia coli mutabilis* Castellani and Chalmers, Man. Trop. Med., 3rd ed., 1919, 943; *Escherichia coli-mutabile* Deere et al., Jour. Bact., *31*, 1936, 625.) From feces. An unstable variant closely related to *Escherichia coli* characterized by irregular lactose fermentation. When cultured on lactose indicator agar, it appears not to ferment lactose. After some days, lactose-fermenting papillae appear growing on or out of the original colonies. Subcultures from these secondary colonies give typical lactose fermentation but subculture from the primary colony, avoiding contact with the papillae, gives delayed fermentation of lactose and when again plated will produce non-fermenting colonies on which fermenting papillae later appear.

Bacillus gastricus Ford. (Ford, Studies from the Royal Victoria Hosp., Montreal, *1*, (5), 1903, 58; also see Jour. Med. Res., *6*, 1901, 213; *Escherichia gastrica* Bergey et al., Manual, 1st ed., 1923, 203.) From feces.

Bacillus gruenthali Morgan. (Das gruenthaler Bacterium, Fischer, Ztschr. f. Hyg., *39*, 1902, 447; Morgan, Brit. Med. Jour., *1*, 1905, 1257; *Bacillus acidi lactici* var. *gruenthali* Levine, Jour. Bact., *3*, 1918, 270; *Bacterium acidilactici* var. *gruenthali* Winslow, Kligler and Rothberg, Jour. Bact., *4*, 1919, 486; *Escherichia gruenthali* Castellani and Chalmers, Manual of Trop. Med., 1919, 942; *Bacterium gruenthali* Weldin and Levine, Abst. Bact., *3*, 1923, 13.) From feces.

Bacillus iliacus Ford. (Ford, Studies from the Royal Victoria Hosp., Montreal, *1*, (5), 1903, 61; also see Jour. Med. Res., *6*, 1901, 213; *Escherichia iliacus* Bergey et al., Manual, 1st ed., 1923, 203; *Proteus iliacus* Bergey et al., Manual, 4th ed., 1934, 363.) From feces.

Bacillus infrequens Ford. (Ford, Studies from the Royal Victoria Hosp., Montreal, *1*, (5), 1903, 42; also see Jour. Med. Res., *6*, 1901, 219.) From feces.

Bacillus jejunales Ford. (Ford, Studies from the Royal Victoria Hosp., Montreal, *1*, (5), 1903, 66; also see Jour. Med. Res., *6*, 1901, 219.) From feces.

Bacillus leporis Migula. (*Bacillus leporis lethalis* Sternberg, Manual of Bacteriology, 1893, 453; *Bacterium leporis lethalis* Chester, Ann. Rept. Del. Col. Agr. Exp. Sta., *9*, 1897, 97; Migula, Syst. Bakt., *2*, 1900, 651; *Eberthella leporis* Bergey et al., Manual, 1st ed., 1923, 229; *Escherichia leporis* Bergey et al., Manual, 2nd ed., 1925, 221.) From feces.

Bacillus para-gruenthali Castellani. (Castellani, 1914, quoted from Castellani and Chalmers, Ann. Past. Inst., *34*, 1920, 614; *Escherichia paragruenthali* Castellani and Chalmers, Manual of Trop. Med., 3rd ed., 1919, 942; *Bacterium coli* var. *paragruenthali* Weldin and Levine, Abst. Bact., *3*, 1923, 13.) From feces. Weldin and Levine (Iowa State Coll. Jour. Sci., *1*, 1926, 132) regard this species as identical with *Bacillus gruenthali* Morgan.

Bacillus plebeius Ford. (Ford, Studies from the Royal Victoria Hosp., Montreal, *1*, (5), 1903, 41; also see Jour. Med. Res., *6*, 1901, 213; *Escherichia plebeia* Bergey et al., Manual, 1st ed., 1923, 203.) From feces.

Bacillus subalcalescens Ford. (Ford, Studies from the Royal Victoria Hosp., Montreal, *1*, (5), 1903, 37; also see Jour. Med. Res., *6*, 1901, 217.) From feces.

Bacillus subgastricus Ford. (Ford, Studies from the Royal Victoria Hosp., Montreal, *1*, (5), 1903, 58; also see Jour. Med. Res., *6*, 1901, 219.) From feces.

Bacillus vekanda Castellani. (Castellani, Jour. Trop. Med. and Hyg., *20*, 1917, 181; *Enteroides vekanda* Castellani and Chalmers, Manual of Trop. Med., 3rd ed., 1919, 941; *Bacterium vekanda* Weldin and Levine, Abst. Bact., *7*, 1923, 13; *Escherichia vekanda* Bergey et al., Manual, 1st ed., 1923, 197.) From feces.

Bacillus vesiculiformans Henrici.

(Henrici, Arb. Bakt. Inst. Hochsch. Karlsruhe, *1*, 1894, 25; *Escherichia vesiculiformans* Bergey et al., Manual, 2nd ed., 1925, 222.) From cheese.

Bacterium chymogenes Ford. (Ford, Studies from the Royal Victoria Hosp., Montreal, *1*, (5), 1903, 63; also see Jour. Med. Res., *6*, 1901, 219.) From feces.

Bacterium coli alcaligenes Chiari and Löffler. (Cent. f. Bakt., I Abt., Orig., *96*, 1925, 95.) From feces.

Bacterium coli anindolicum Lembke. (Lembke, Arch. f. Hyg., *26*, 1896, 299; *Bacillus anindolicum* Chester, Man. Determ. Bact., 1901, 207; *Escherichia anindolica* Bergey et al., Manual, 3rd ed., 1930, 325.) From feces.

Bacterium coli imperfectum Roelcke. (Cent. f. Bakt., I Abt., Orig., *145*, 1939, 109.) From feces. Lactose not fermented.

Bacterium formicum Omelianski. (Omelianski, Cent. f. Bakt., II Abt., *11*, 1904, 184; *Achromobacter formicum* Bergey et al., Manual, 1st ed., 1923, 144; *Escherichia formica* Bergey et al., Manual, 2nd ed., 1925, 220.) From soil.

Bacterium galactophilum Ford. (Ford, Studies from the Royal Victoria Hosp., Montreal, *1*, (5), 1903, 39; also see Jour. Med. Res., *6*, 1901, 217; *Escherichia galactophila* Bergey et al., Manual, 1st ed., 1923, 202.) From feces.

Bacterium succinicum Sakaguchi and Tada. (Cent. f. Bakt., II Abt., *101*, 1940, 341.) From cheese.

Bacterium uromutabile Koch. (Cent. f. Bakt., I Abt., Orig., *133*, 1935, 209.) From genito-urinary infections. A non-lactose-fermenting variety that developed the ability to ferment lactose slowly.

Bacterium vesiculosum Henrici. (Arb. bakt. Inst. Karlsruhe, *1*, Heft 1, 1894, 37; *Bacillus vesiculosus* MacConkey, Jour. Hyg., *9*, 1909, 86; *Escherichia vesiculosa* Castellani and Chalmers, Man. Trop. Med., 3rd ed., 1919, 942.) From cheese.

Escherichia alba Schrire. (Trans. Royal Soc. So. Africa, *17*, 1928, 43.) From feces.

Escherichia brasiliensis Mello. (Sao Paulo Medico, Anno 10, *2*, 1937, 11.) From feces.

Escherichia colofoetida (Castellani) Hauduroy et al. (*Bacillus colofoetidus* Castellani, Jour. Trop. Med. and Hyg., 1930, 134; Hauduroy et al., Dict. d. Bact. Path., 1937, 226.) From feces.

Escherichia coloides (Castellani) Castellani and Chalmers. (*Bacillus coloides* var. *A* and *Bacillus coloides* var. *B*, Castellani; Castellani and Chalmers, Manual of Trop. Med., 1919, 942 and 946.) From feces.

Escherichia colotropicalis (Castellani) Castellani and Chalmers. (*Bacillus colotropicalis* Castellani, 1907; see Castellani and Chalmers, Manual of Trop. Med., 3rd ed., 1919, 942 and 946.) From feces.

Escherichia ellingeri (Metalnikov and Chorine) Bergey et al. (*Coccobacillus ellingeri* Metalnikov and Chorine, Ann. Inst. Past., *42*, 1928, 1635; Bergey et al., Manual, 3rd ed., 1930, 330.) Causes fatal infection in insects as *Pyrausta nubilalis* Hübn. (European corn borer) and *Galleria mellonella* L. (bee moth). See Manual, 5th ed., 1939, 606 for a description of this species.

Escherichia khartoumensis (Chalmers and Macdonald) Hauduroy et al. (*Bacillus khartoumensis* Chalmers and Macdonald, 1915; see Castellani and Chalmers, Manual of Trop. Med., 3rd ed., 1919, 948; *Enteroides khartoumensis* Castellani and Chalmers, *ibid.*, 941; Hauduroy et al., Dict. d. Bact. Path., 1939, 230.) From feces.

Escherichia metacoli (Castellani) Castellani and Chalmers. (*Bacillus metacoli* Castellani, 1915; see Castellani and Chalmers, Manual of Trop. Med., 3rd ed., 1919, 942 and 948.) From feces.

Escherichia metacoloides (Castellani) Castellani and Chalmers. (*Bacillus metacoloides* Castellani; see Castellani and Chalmers, Manual of Trop. Med., 3rd ed., 1919, 942 and 950.) From feces.

Escherichia paradoxa (Toumanoff) Hauduroy et al. (*Colibacillus paradoxus* Toumanoff, Bull. Soc. Centr. de Méd. Vétér., *80*, 1927, 367; Hauduroy et al., Dict. d. Bact. Path., 1937, 231.) From feces.

Escherichia paraenterica (Castellani) Hauduroy et al. (*Bacillus paraentericus* Castellani, Manual of Trop. Med., 1st ed., 1910, 991; *Enteroides paraenterica* Castellani and Chalmers, *ibid.*, 3rd ed., 1919, 941; Hauduroy et al., Dict. d. Bact. Path., 1937, 231.) From feces.

Escherichia pauloensis Mello. (Ass. Paulista de Medicina, *11*, 1937, 73.) From feces.

Escherichia pseudocoli (Castellani) Castellani and Chalmers. (*Bacillus pseudo-coli* Castellani, Manual of Trop. Med., 1st ed., 1910, 990; Castellani and Chalmers, Manual Trop. Med., 3rd ed., 1919, 942.) From feces.

Escherichia pseudo-coliformis (Castellani) Hauduroy et al. (*Bacillus pseudo-coliformis* Castellani, 1917; see Castellani and Chalmers, Manual of Trop. Med., 3rd ed., 1919, 952; Hauduroy et al., Dict. d. Bact. Path., 1937, 233.) From feces.

Escherichia pseudocoloides (Castellani) Castellani and Chalmers. (*Bacillus pseudocoloides* Castellani, 1916; see Castellani and Chalmers, Manual of Trop. Med., 3rd ed., 1919, 954; *ibid.*, 942; *Bacterium pseudo-coloides* Weldin and Levine, Abst. Bact., *7*, 1923, 13.) From feces.

Escherichia pseudocoscoroba Castellani and Chalmers. (*Bacillus coscoroba* MacConkey, Jour. Hyg., *6*, 1906, 570; not *Bacillus coscoroba* Trétrop, Ann. Inst. Past., *14*, 1900, 224; *Bacterium coscorobae* Bergey and Deehan, Jour. Med. Res., *19*, 1908, 182; Castellani and Chalmers, Man. Trop. Med., 3rd ed., 1919, 942; *Bacillus communior* var. *coscoroba* Winslow, Kligler and Rothberg, Jour. Bact., 4, 1919, 486; *Escherichia coscoroba* Weldin, Iowa State Coll. Jour. Sci., *1*, 1926, 139.) From feces and sewage. This organism described by MacConkey is quite different from the organism described by Trétrop (see *Pasteurella* appendix).

Escherichia pseudodysenteriae Bergey et al. (*Bacterium pseudodysenteriae* Kruse, Deutsche Med. Wchnschr., *27*, 1901, 386; Bergey et al., Manual, 1st ed., 1923, 198.) From feces of normal persons and of dysentery patients.

Genus II. Aerobacter *Beijerinck.**

(Beijerinck, Cent. f. Bakt., II Abt., *6*, 1900, 193; *Aerogenesbacterium* Orla-Jensen, Jour. Bact., *6*, 1921, 272; *Colobactrum* (in part) Borman, Stuart and Wheeler, Jour. Bact., *48*, 1944, 357.) From Latin, air or gas, and rod.

Short rods, fermenting glucose and lactose with acid and gas production. Methyl red test negative; Voges-Proskauer test positive. Form two or more times as much carbon dioxide as hydrogen from glucose; trimethyleneglycol not produced from glycerol by anaerobic fermentation; citric acid and salts of citric acid utilized as sole source of carbon. Grow readily on ordinary media. Facultative anaerobes. Widely distributed in nature.

The type species is *Aerobacter aerogenes* (Kruse) Beijerinck.

NOTE: Kligler (Jour. Inf. Dis., *15*, 1914, 187) found the fermentation of glycerol to be inversely correlated with gelatin liquefaction and considered the former the more reliable due to occasional loss of gelatin liquefying ability. This was confirmed by Levine (Amer. Jour. Pub. Health, *7*, 1917, 784) who reports that the two characters do not correlate perfectly. Griffin and Stuart (Jour. Bact., *40*, 1940, 93ff.) find a similar correlation of characters but feel that because these characters do not correlate perfectly, it would be better to combine the two species into a single species.

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* Completely revised by Prof. M. W. Yale, New York State Experiment Station, Geneva, New York, Nov., 1938; further revision, July, 1943.

Key to the species of genus **Aerobacter.**

I. Glycerol fermented with acid and gas.
   A. Gelatin not liquefied (rarely liquefied).
      1. *Aerobacter aerogenes.*

II. Glycerol fermented with no visible gas.
   A. Gelatin liquefied.
      2. *Aerobacter cloacae.*

1. **Aerobacter aerogenes** (Kruse) Beijerinck. (*Bacterium lactis aerogenes* Escherich, Fortschr. d. Med., *3*, 1885, 515; *Bacterium lactis* Baginsky, Ztschr. f. phys. Chem., *12*, 1888, 437; not *Bacterium lactis* Lister, Quart. Jour. Micro. Sci., *13*, 1873, 380; *Bacterium aceticum* Baginsky, *ibid.*; *Bacillus lactantium* Trevisan, I generi e le specie delle Batteriacee, 1889, 15; *Bacillus lactis aerogenes* Sternberg, Manual of Bacteriology, 1893, 447; *Bacillus aerogenes* Kruse, in Flügge, Die Mikroorganismen, *2*, 1896, 340; not *Bacillus aerogenes* Miller, Deutsche med. Wchnschr., *12*, 1886, 119; *Bacterium aerogenes* Chester, Del. Agr. Exp. Sta., 9th Ann. Rept., 1897, 53; not *Bacterium aerogenes* Miller, *loc. cit.*; Beijerinck, Arch. néerl. d. sci. exact. et nat., *4*, 1900, 1; *Encapsulatus lactis-aerogenes* Castellani and Chalmers, Manual of Trop. Med., 1919, 934; (*Encapsulata*) *Bacillus aerogenes* Perkins, Jour. Inf. Dis., *37*, 1925, 254; *Colobactrum aerogenes* Borman, Stuart and Wheeler, Jour. Bact., *48*, 1944, 358.) From Latin, gas-producing.

Rods: 0.5 to 0.8 by 1.0 to 2.0 microns, occurring singly. Frequently capsulated. (A variety showing a transverse arrangement of the capsule has been named *Aerobacter transcapsulatus* by Thompson, Jour. Bact., *28*, 1934, 41.) Usually non-motile. Gram-negative.

Gelatin colonies: Thick, porcelain-white, opaque, moist, smooth, entire.

Gelatin stab: Thick, spreading, white, opaque surface growth. No liquefaction.

Agar colonies: Thick, white, raised, moist, smooth, entire. More convex than colonies of *Escherichia coli* and often mucoid.

Agar slant: Abundant, thick, white, moist, glistening, spreading growth.

Broth: Turbid, with pellicle and abundant sediment.

Litmus milk: Acid with coagulation. No peptonization.

Potato: Thick, yellowish-white to yellowish-brown, spreading with nodular outgrowths over the surface.

Indole may or may not be formed (Ford, Studies from the Royal Victoria Hospital, Montreal, *1*, 1901–1903, 16; Bardsley, Jour. Hyg. (Eng.), *34*, 1934, 38; Wilson, Med. Res. Council, London, Spec. Rept. Ser. 206, 1935, 161).

Nitrites produced from nitrates.

Methyl red test negative (Clark and Lubs, Jour. Inf. Dis., *17*, 1915, 160); Voges-Proskauer test positive (Durham, Jour. Exp. Med., *5*, 1901, 373); inverse correlation between methyl red and Voges-Proskauer tests (Levine, Jour. Bact., *1*, 1916, 153).

Citric acid and salts of citric acid utilized as sole source of carbon (Koser, Jour. Bact., *8*, 1923, 493).

Uric acid utilized as sole source of nitrogen (Koser, Jour. Inf. Dis., *23*, 1918, 377).

Gas ratio: Two or more volumes of carbon dioxide to one of hydrogen formed from glucose (Harden and Walpole, Proc. Roy. Soc. Series B, *77*, 1905, 399; Rogers, Clark and Davis, Jour. Inf. Dis., *14*, 1914, 411).

Catalase produced.

Hydrogen sulfide not produced in peptone iron agar (Levine, Epstein and Vaughn, Amer. Jour. Pub. Health, *24*, 1934, 505; Tittsler and Sandholzer, Amer. Jour. Pub. Health, *27*, 1937, 1240). More sensitive indicators give positive

tests for hydrogen sulfide (Hunter and Weiss, Jour. Bact., *35*, 1938, 20).

Trimethyleneglycol not produced from glycerol by anaerobic fermentation (Braak, Onderzoekingen over Vergisting van Glycerine, Thesis, Delft, 1928, 212; Werkman and Gillen, Jour. Bact., *23*, 1932, 167).

Sodium hippurate hydrolyzed (Hajna and Damon, Amer. Jour. Hyg., *19*, 1934, 545).

Acid and gas from glucose, galactose, lactose, fructose, arabinose, maltose, raffinose, cellobiose, salicin, esculin, starch, dextrin, glycerol, mannitol, sorbitol and inositol, α-methyl-glucoside usually fermented (Koser and Saunders, Jour. Bact., *24*, 1932, 267). Sucrose, inulin, dulcitol and adonitol may or may not be fermented. Protopectin not fermented. Variable fermentation of sucrose and mannitol (Sherman and Wing, Jour. Bact., *33*, 1937, 315).

Aerobic, facultative.

Growth requirements: Good growth on ordinary laboratory media. Optimum growth temperature about 30°C. Grows better at temperatures below 30°C than does *Escherichia coli*. Usually destroyed in 30 minutes at 60°C, but certain heat-resistant strains may withstand this exposure (Ayers and Johnson, Jour. Agr. Res., *3*, 1914, 401; Stark and Patterson, Jour. Dairy Sci., *19*, 1936, 495). Gas not produced in Eijkmann test when carried out at 45° to 46°C (Eijkmann, Cent. f. Bakt., I Abt., Orig., *37*, 1904, 74; Levine, Epstein and Vaughn, Amer. Jour. Pub. Health, *24*, 1934, 505).

Habitat: Normally found on grains and plants and to a varying degree in the intestinal canal of man and animals. Widely distributed in nature.

2. Aerobacter cloacae (Jordan) Bergey et al. (*Bacillus cloacae* Jordan, Rept. Mass. State Bd. of Health, Part II, 1890, 836; *Bacterium cloacae* Lehmann and Neumann, Bakt. Diag., 1 Aufl., *2*, 1896, 239; *Bacillus lactis cloacae* Conn, Esten and Stocking, Storrs Agr. Exp. Sta., Conn., 18th Ann. Rept. for 1906, 180; *Cloaca cloacae* Castellani and Chalmers, Man. Trop. Med., 3rd ed., 1919, 938; Bergey et al., Manual, 1st ed., 1923, 207.) From Latin *cloaca*, sewer.

The following are also regarded as identical with *Aerobacter cloacae: Aerobacter liquefaciens* Grimes and Hennerty, Sci. Proc. Royal Dublin Society, (N. S.) *20*, 1931, 93; not *Aerobacter liquefaciens* Beijerinck, Cent. f. Bakt., II Abt., *6*, 1900, 199 (monotrichous); *Bacillus levans* Wolffin, Arch. f. Hyg., *21*, 1894, 279 and Lehmann, Cent. f. Bakt., *15*, 1894, 350 (*Bacterium levans* Lehmann and Neumann, Bakt. Diag., 1 Aufl., *2*, 1896, 235; *Cloaca levans* Castellani and Chalmers, Man. Trop. Med., 3rd ed., 1919, 938; *Aerobacter levans* Bergey et al., Manual, 1st ed., 1923, 208).

Rods: 0.5 to 1.0 by 1.0 to 2.0 microns, occurring singly. Usually motile possessing peritrichous flagella. Not capsulated. Gram-negative.

Gelatin colonies: Thin, circular, bluish, translucent.

Gelatin stab: Slow liquefaction. Liquefying power sometimes lost (Kligler, Jour. Inf. Dis., *15*, 1914, 199).

Agar colonies: Circular, thick, opaque with white center, entire.

Agar slant: Porcelain-white, smooth, glistening, spreading growth.

Broth: Turbid, with thin pellicle.

Litmus milk: Acid, coagulation, gas, slow peptonization.

Potato: Growth yellowish, moist, glistening.

Indole not formed (Levine, Epstein and Vaughn, *loc. cit.*; Wilson, Med. Res. Council, London, Spec. Rept. Ser. 206, 1935, 161).

Nitrites produced from nitrates.

Methyl red test negative; Voges-Proskauer test positive.

Citric acid and salts of citric acid utilized as sole source of carbon (Koser, Jour. Bact., *8*, 1923, 493).

Uric acid utilized as sole source of

nitrogen (Koser, Jour. Inf. Dis., *23*, 1918, 377).

Gas ratio: Glucose fermented with at least two volumes of carbon dioxide to one of hydrogen (Rogers, Clark and Davis, Jour. Inf. Dis., *14*, 1914, 411).

Catalase produced.

Hydrogen sulfide not produced in peptone iron agar (Levine, Epstein and Vaughn, Amer. Jour. Pub. Health, *24*, 1934, 505).

Sodium hippurate not hydrolyzed (Hajna and Damon, Amer. Jour. Hyg., *19*, 1934, 545).

Acid and gas from glucose, fructose, galactose, arabinose, xylose, lactose, maltose, raffinose, dextrin, salicin, trehalose, mannitol, sorbitol, cellobiose and α-methyl-glucoside. Sucrose usually fermented. Inulin, esculin, starch, dulcitol, rhamnose and protopectin not attacked. Glycerol fermented with no visible gas (Kligler, *loc. cit.*, 187; Levine, Amer. Jour. Pub. Health, *7*, 1917, 784). Starch rarely fermented (Levine, *ibid.*). See Winslow, Kligler and Rothberg, Jour. Bact., *4*, 1919, 429 for review of literature.

Fecal odor produced.

Aerobic, facultative.

Growth requirements: Good growth on ordinary laboratory media. Optimum growth temperature 30° to 37°C. Gas not produced in Eijkmann test when carried out at 45° to 46°C (Levine, Epstein and Vaughn, *loc. cit.*).

Habitat: Found in human and animal feces, sewage, soil and water.

Appendix: The following described species have been placed in *Aerobacter* or may belong here:

Actinobacter polymorphus Duclaux. (Duclaux, Ann. Inst. Nat. Agron., *5*, 1882, 110; *Bacillus actinobacter* Migula, Syst. d. Bakt., *2*, 1900, 689.) Causes swelling of cheese. Possibly this was *Aerobacter cloacae*.

Aerobacter chinense Bergey et al. (*Bacillus capsulatus chinensis* Hamilton, Cent. f. Bakt., II Abt., *4*, 1898, 230; *Bacterium chinense* Migula, Syst. d. Bakt., *2*, 1900, 357; Bergey et al., Manual, 1st ed., 1923, 207.) From India ink.

Aerobacter decolorans Burkey. (Iowa State Coll. Jour. Sci., *3*, 1928, 77.) From rotted potato and hay infusions.

Aerobacter diversum Burkey. (Iowa State Coll. Jour. Sci., *3*, 1928, 77.) From soil.

Aerobacter faeni Burkey. (Iowa State Coll. Jour. Sci., *3*, 1928, 77.) From hay infusions.

Aerobacter hibernicum Grimes and Hennerty. (Sci. Proc. Royal Dublin Society, (N.S.) *20*, 1931, 92.) From butter.

Aerobacter leporis Botta. (Giorn. Batteriol. e Immunol., *23*, 1939, 217.) From liver abscess in a rabbit.

Aerobacter melezitovorum Burkey. (Iowa State Coll. Jour. Sci., *3*, 1928, 77.) From soil.

Aerobacter pectinovorum Burkey. (Iowa State Coll. Jour. Sci., *3*, 1928, 77.) From creek water.

Aerobacter oxytocum (Trevisan) Bergey et al. (*Bacillus oxytocus perniciosus* Flügge, Die Mikroorganismen, 1886, 268; *Bacillus oxytocus* Trevisan, I generi e le specie delle Batteriacee, 1889, 17; *Bacterium oxytocus perniciosus* Chester, Ann. Rept. Del. Col. Agr. Exp. Sta., *9*, 1897, 139; *Bacterium oxytocum* Migula, Syst. d. Bakt., *2*, 1900, 394; *Escherichia oxytocus* Castellani and Chalmers, Manual of Trop. Med., 3rd ed., 1919, 942; Bergey et al., Manual, 1st ed., 1923, 206.) From old milk.

Aerobacter paraoxytocum Mello. (Jorn. Dos Clinicos, No. 15, 1937.) From a dental abscess.

Bacillus aceris Edson and Carpenter. (Edson and Carpenter, Vermont Agr. Exp. Sta. Bull. 167, 1912, 475; *Achromobacter aceris* Bergey et al., Manual, 4th ed., 1934, 218.) From slimy maple sap. See Manual, 5th ed., 1939, 506 for a description of this organism. Identified by Fabian (Ind. and Eng. Chem., *27*, 1935, 349) as *Aerobacter aerogenes*.

Bacillus aromaticus Pammel. (Pammel, Bull. No. 21, Iowa Agr. Exper. Sta., 1893, 792; Pammel and Pammel, Cent. f. Bakt., II Abt., *2*, 1896, 633; *Bacterium aromaticus* Chester, Ann. Rept. Del. Col. Agr. Exp. Sta., *9*, 1897, 100; *Flavobacterium aromaticum* Bergey et al., Manual, 1st ed., 1923, 105.) From cabbage. Used as a starter for cheese making. Acid and gas from glucose and sucrose. See Manual, 5th ed., 1939, 533 for a description of this organism.

Bacillus guillebeau a, *b* and *c*, von Freudenreich. (Ann. de Micrographie, *2*, 1890, 353.) From mastitis milk. Culture *a* may well have been *Aerobacter aerogenes*, *b* appears to have been *A. cloacae* while *c* was a mucoid variant (see Sternberg, Man. of Bact., 1893, 725).

Bacillus subcloacae Ford. (Studies from the Royal Victoria Hosp., Montreal, *1*, (5), 1903, 60; also see Ford, Jour. Med. Res., *6*, 1901, 213.) From feces.

Bacterium liquefaciens Ford. (Studies from the Royal Victoria Hosp., Montreal, *1*, (5), 1903, 59; also see Ford, Jour. Med. Res., *6*, 1901, 215.) From feces. While Ford regards this species as identical with *Bacillus liquefaciens* Eisenberg, neither is adequately described and they differ in important characters. The same holds true for *Bacillus liquefaciens* Fuller and Johnson, Jour. Exp. Med., *4*, 1899, 627.

Bacterium margaritaceum Migula. (Perlschnurbacillus, Maschek, Bakteriol. Untersuch. d. Leitmeritz. Trinkwässer, Leitmeritz, 1887; Migula, Syst. d. Bakt., *2*, 1900, 422 and 1059.) From water. Possibly identical with *Aerobacter aerogenes*.

Bacterium subliquefaciens Ford. (Studies from the Royal Victoria Hosp., Montreal, *1*, (5), 1903, 59; also see Ford, Jour. Med. Res., *6*, 1901, 219.) From feces.

Bacterium zeae Comes. (Bacterial Disease of Corn, Burrill, Ill. Agr. Exp. Sta. Bull. 6, 1889, 164; Comes, Crittogamia Agraria, *1*, 1891, 500; *Bacillus secalis* Ludwig, Lehrbuch der niederen Kryptogamen, 1892, 95; *Bacillus zeae* Russell, Bacteria in their relation to vegetable tissue, Thesis, Johns Hopkins Univ., Baltimore, 1892, 36.) From corn blight. Moore (Agric. Sci., *8*, 1894, 368) identified a culture received from Burrill as *Bacillus cloacae* Jordan.

Burkey (Iowa State College Jour. Sci., *3*, 1928, 77) described five species (*Aerobacter indologenes*, *Aerobacter motorium*, *Aerobacter mitificans*, *Aerobacter salicinovorum* and *Aerobacter pseudoproteus*) which are regarded as varieties of *Aerobacter cloacae*.

Genus III. **Klebsiella** *Trevisan.**

(Trevisan, Atti della accad. Fisio-Medico-Statistica in Milano, Ser. 4, *3*, 1885, 105; *Calymmatobacterium* Aragão and Vianno, Mem. Inst. Oswaldo Cruz, *4*, 1912, 222; *Encapsulatus* Castellani and Chalmers, Man. Trop. Med., 3rd ed., 1919, 934.) Named for Edwin Klebs (1834–1913), early German bacteriologist.

Short rods, somewhat plump with rounded ends, mostly occurring singly. Encapsulated in the mucoid phase. Non-motile. Gram-negative. Fermentation reactions are highly variable but usually a number of carbohydrates are fermented. Nitrites are produced from nitrates. Aerobic, growing well on ordinary culture media. Encountered frequently in the respiratory, intestinal and genito-urinary tracts of man, but may be isolated from a variety of animals and materials.

The type species is *Klebsiella pneumoniae* (Schroeter) Trevisan.

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* Rearranged by Prof. M. W. Yale, New York State Experiment Station, Geneva, New York, Nov., 1938; further revision by Dr. O. B. Chapman, Syracuse Medical College, Syracuse, New York, December, 1945.

1. **Klebsiella pneumoniae** (Schroeter) Trevisan. (Pneumoniecoccus, Friedlaender, Arch. f. Path. Anat., *87*, 1882, 319; *Bacterium pneumonie crouposae* Zopf, Die Spaltpilze, 3 Aufl., 1885, 66; *Klebsiella crouposa* Trevisan, Atti della Accad. Fisio-Medico-Statistica in Milano, Ser. 4, *3*, 1885, 105; *Hyalococcus pneumoniae* Schroeter, in Cohn, Kryptogamen Flora von Schlesien, *3*(1), 1886, 152; *Bacillus pneumoniae* Flügge, Die Mikroorganismen, 2 Aufl., 1886, 204; Trevisan, Rend. d. R. Istit. Lombardo, Ser. 2, *20*, 1887, 94; *Klebsiella friedlanderi* Trevisan, I generi e le specie delle Batteriacee, 1889, 26; *Bacillus mucosus capsulatus* Paulsen, Mittheil. f. d. Verein Schleswig-Holsteiner Aerzte, *2*, 1893, No. 7; *Bacterium pneumoniae* Lehmann and Neumann, Bakt. Diag., 1 Aufl., *2*, 1896, 200; *Bacterium pneumonicum* Migula, Syst. d. Bakt., *2*, 1900, 350; *Bacillus friedlanderi* Macé, Traité Pratique de Bact., 4th ed., 1901, 771; *Encapsulatus pneumoniae* Castellani and Chalmers, Man. Trop. Med., 3rd ed., 1919, 934; *Coccobacillus friedlanderi* Neveu-Lemaire, Précis Parasitol. Hum., 5th ed., 1921, 20; *Proteus pneumoniae* Weldin, Iowa State Coll. Jour. Sci., *1*, 1926, 149; *Bacterium friedlander* Weldin, *idem; Bacillus mucosus-capsulatus* Mason and Beattie, Arch. of Internal Med., *42*, 1928, 331.) From Greek, of pneumonia.

Rods: 0.3 to 0.5 by 5.0 microns, with rounded ends, often four to five times as long as broad, occurring singly and in pairs. Encapsulated. Non-motile. Gram-negative.

Gelatin colonies: Dirty-white, smooth, opaque, entire, slightly raised.

Gelatin stab: Dirty-white surface growth. Filiform growth in stab. No liquefaction. Gas bubbles.

Agar colonies: White, shiny, convex, smooth, glistening, entire.

Agar slant: Slimy, white, somewhat translucent, raised growth.

Broth: Turbid, with thick ring or film.

Litmus milk: Variable.

Potato: Yellowish, slimy, raised growth. Gas is formed.

Nitrites produced from nitrates.

Indole variable, usually not formed.

Fermentation of carbohydrates highly variable. Acid and gas may be formed from glucose, lactose, sucrose, fructose, galactose, maltose, mannitol and inositol.

Methyl red test variable.

Acetylmethylcarbinol production variable.

Blood agar: Usually no hemolysis.

Utilization of citrate as a sole source of carbon variable.

Aerobic, facultative.

Optimum temperature 37°C.

Common name: Friedländer's pneumobacillus.

Source: Originally isolated from sputum in pneumonia.

Habitat: Associated with infections of the respiratory, intestinal and genitourinary tracts of man. Encountered in infections of animals and may be isolated from a wide variety of sources.

NOTE: The difficulty experienced in distinguishing members of this genus from those of *Escherichia* and *Aerobacter* is recognized. The members of these three genera exist in at least three growth phases, mucoid (capsulated), smooth and rough.

Working with the mucoid phase of *Klebsiella*, Julianelle (Jour. Exp. Med., *44*, 1926, 113, 683, 735; *52*, 1930, 539) described three serological types, A, B and C on the basis of capsular specific polysaccharides. There is evidence that other types exist. The presence of a generic specific somatic antigen pattern has not been definitely accepted.

Appendix: The following organisms may be placed in *Klebsiella*. The evidence for differentiating them into distinct species is so meagre that for the present it may be better to consider them as varieties of *Klebsiella pneumoniae*.

Klebsiella adanti Hauduroy et al.

(Dict. d. Bact. Path., 1937, 260.) From a case of pyelocystitis.

Klebsiella capsulata (Sternberg) Bergey et al. (Kapselbacillus, Pfeiffer, Ztschr. f. Hyg., *6*, 1889, 145; *Bacillus capsulatus* Sternberg, Manual of Bact., 1893, 431; *Bacterium capsulatum* Migula, Syst. d. Bakt., *2*, 1900, 349; *Encapsulatus pfeifferi* Bergey et al., Manual, 1st ed., 1923, 239; Bergey et al., Manual, 2nd ed., 1925, 265.) From purulent exudate from stomach of a guinea pig.

Klebsiella crassa Trevisan. (*Bacillus sputigenus crassus* Kreibohm, Inaug. Diss., Göttingen, 1889; abst. in Cent. f. Bakt., *7*, 1890, 313; *Bacillus crassus sputigenus* Flügge, Die Mikroorganismen, 2 Aufl., 1886, 260; Trevisan, I generi e le specie delle Batteriacee, 1889, 25; *Bacterium sputigenes crassus* Chester, Ann. Rept. Del. Col. Agr. Exp. Sta., *9*, 1897, 88; *Bacterium crassum* Chester, Man. Determ. Bact., 1901, 151.) From sputum.

Klebsiella cuniculi Hauduroy et al. (*Bacillus capsulatus pyaemiae cuniculi* Koppinayi, Ztschr. f. Tiermed., *11*, 1907, 429; Hauduroy et al., Dict. d. Bact. Path., 1937, 262.) From pleuropericarditis in a rabbit.

Klebsiella genitalium (Dimock and Edwards) Hauduroy et al. (*Encapsulatus genitalium* Dimock and Edwards, Jour. Amer. Veter. Assoc., *70*, 1927, 469; Hauduroy et al., Dict. d. Bact. Path., 1937, 264.) From infections in the genito-urinary organs of mares.

Klebsiella granulomatis (Aragão and Vianna) Bergey et al. (*Calymmatobacterium granulomatis* Aragão and Vianna, Mem. do Inst. Oswaldo Cruz, Rio de Janeiro, *4*, 1912, 211; *Encapsulatus inguinalis* Bergey et al., Manual, 1st ed., 1923, 238; Bergey et al., Manual, 2nd ed., 1925, 264.) From granuloma inguinale.

Klebsiella ozaenae (Abel) Bergey et al. (*Bacillus mucosus ozaenae* Abel, Cent. f. Bakt., *13*, 1893, 167; *Bacillus ozaenae* Abel, *ibid.*, 172; not *Bacillus ozaenae* Migula, Syst. d. Bakt., *2*, 1900, 645, 662; ?*Bacillus capsulatus mucosus* Fasching, Sitzgsber. Wien. Akad., III Abt., *100*, 1891 (*Bacterium capsulatus mucosus* Chester, Ann. Rept. Del. Col. Agr. Exp. Sta., *9*, 1897, 130; *Bacterium faschingii* Migula, Syst. d. Bakt., *2*, 1900, 355; *Bacillus capsulatus-mucosus* Holland, Jour. Bact., *5*, 1920, 217; *Bacterium mucosum capsulatum* Holland, *ibid.*, 221; *Bacterium mucosum-capsulatum* Holland, *ibid.*, 217); *Bacterium ozaenae* Lehmann and Neumann, Bakt. Diag., 1 Aufl., *2*, 1896, 204; *Bacterium mucosus ozaena* Chester, Ann. Rept. Del. Col. Agr. Exp. Sta., *9*, 1897, 138; *Encapsulata ozenae* Bergey et al., Manual, 1st ed., 1923, 240; Bergey et al., Manual, 2nd ed., 1925, 266.) From cases of ozena.

Klebsiella paralytica Cahn, Wallace and Thomas. (Wallace, Lyell, Thomas, Alvin and Cahn, Proc. Soc. Exp. Biol., *29*, 1932, 1908; Cahn, Wallace and Thomas, Science, *76*, 1932, 385; Wallace, Cahn and Thomas, Jour. Inf. Dis., *53*, 1933, 386; *Klebsiella alcis* Hauduroy et al., Dict. d. Bact. Path., 1937, 260.) From intestine of tick (*Dermacentor albipictus*) and thought to be the cause of tick paralysis of moose.

Klebsiella rhinoscleromatis Trevisan. (Rhinoscleromabacillus, v. Frisch, Wien. med. Wchnschr., 1882; Cornil, Progrès Medical, 1883; Trevisan, Rend. d. R. Istit. Lombardo, Ser. 2, *20*, 1887, 95; *Bacterium rhinoscleromatis* Migula, Syst. d. Bakt., *2*, 1900, 352; *Bacterium nasalis* Chester, Man. Determ. Bact., 1901, 134; *Bacillus rhinoscleromatis* Winslow, Kligler and Rothberg, Jour. Bact., *4*, 1919, 491.) From cases of rhinoscleroma.

*Appendix I. Tribe Eschericheae: Borman, Wheeler and Stuart (Jour. Bact., *48*, 1944, 361) place coliform-like bacteria that are slow lactose-fermenters in a separate genus *Paracolobactrum* as follows:

Genus A. **Paracolobactrum** *Borman, Stuart and Wheeler.*

(Paracolibacille, Widal and Nobecourt, Semaine Méd., *17*, 1897, 285; Borman, Stuart and Wheeler, Jour. Bact., *48*, 1944, 361.)

Short rods characterized by consistently delayed fermentation of lactose (occasionally negative). Glucose is fermented with formation of visible gas. Certain forms attack carbohydrates characteristically at 20° to 30°C but not at 37°C. Antigenic relationships to other genera in the family are common, even with respect to major antigens.

The type species is *Paracolobactrum aerogenoides* Borman, Stuart and Wheeler.

Key to the species of genus **Paracolobactrum.**

I. Acetylmethylcarbinol produced.
  1. *Paracolobactrum aerogenoides.*

II. Acetylmethylcarbinol not produced.
  A. Citric acid utilized as a sole source of carbon.
    2. *Paracolobactrum intermedium.*
  B. Citric acid not utilized as a sole source of carbon.
    3. *Paracolobactrum coliforme.*

1. **Paracolobactrum aerogenoides** Borman, Stuart and Wheeler. (Para-aerogenes, Stuart, Wheeler, Rustigian and Zimmerman, Jour. Bact., *45*, 1943, 117; Borman, Stuart and Wheeler, Jour. Bact., *48*, 1944, 361.) Latinized, resembling *aerogenes.*

Characters as for *Aerobacter aerogenes* and *Aerobacter cloacae* except for consistently delayed fermentation of lactose.

Source: From human gastroenteritis.

Habitat: Surface water, soils, grains, as well as the intestinal tract of animals, including man.

2. **Paracolobactrum intermedium** Borman, Stuart and Wheeler. (Parafreundii, Stuart et al., Jour. Bact., *45*, 1943, 117; Borman, Stuart and Wheeler, Jour. Bact., *48*, 1944, 361.) From Latin *intermedius*, intermediate.

Characters as for *Escherichia freundii* and *Escherichia intermedium* except for consistently delayed fermentation of lactose.

Source: From human gastroenteritis.

Habitat: Surface water, soil, grains, as well as the intestinal tract of animals, including man.

3. **Paracolobactrum coliforme** Borman, Stuart and Wheeler. (Para-coli, Stuart et al., Jour. Bact., *45*, 1943, 117; Borman, Stuart and Wheeler, Jour. Bact., *48*, 1944, 361.) Latinized, resembling *coli.*

Characters as for *Escherichia coli* except for consistently delayed fermentation of lactose.

Source: From human gastroenteritis.

Habitat: Surface water, soil, grains, as well as intestinal tract of animals, including man.

NOTE: The following also belong here:

Bacterium paracoli Stutzer and Wsorow. (Non-lactose-fermenting *Bacterium coli*, Gilbert and Lion, Semaine Méd., *13*, 1893, 130; Stutzer and Wsorow, Cent. f. Bakt., II Abt., *71*, 1927, 115.) From intestines of healthy larvae of a moth (*Euxoa segetum*).

Salmonella para-colon (Day) Hauduroy et al. (*Bacillus para-colon* Day; see Castellani, Cent. f. Bakt., I Abt., Orig., *65*, 1912, 264; also Castellani and Chalmers, Man. Trop. Med., 3rd ed., 1919, 950; Hauduroy et al., Dict. d. Bact. Path., 1937, 461.)

* Prepared by Dr. E. K. Borman, Bureau of Laboratories, State Department of Health, Hartford, Connecticut, July, 1945.

*Appendix II. Tribe Eschericheae: Gram-negative, peritrichous to non-motile rods similar to organisms placed in *Paracolobactrum*, *Serratia* and *Salmonella* have recently been described as causing diseases of reptiles, birds and mammals. They may be grouped here although they have been placed in several different genera.

1. **Bacterium sauromali** Conti and Crowley. (Jour. Bact., *36*, 1938, 269.) From a generic name of lizards, *Sauromalus*.

Short rods: 0.2 to 0.5 by 1.0 to 2.0 microns, with rounded ends, occurring in groups. Motile with 4 to 6 peritrichous flagella. Gram-negative.

Gelatin: Infundibuliform liquefaction complete in 3 days at 37°C. Black sediment. Medium browned.

Agar slant: Growth abundant, spreading, convex, faint yellowish-green, glistening, smooth, translucent, butyrous. Decided odor. Medium greened.

Nutrient broth: After 1 day at 37°C, moderate turbidity. Ring. Decided odor. Scanty flocculent sediment.

Milk: Alkaline and complete peptonization in ten days.

Indole not formed.

Potato: Growth yellowish-green to olive.

Blood medium: Complete alpha hemolysis in 48 hours.

Peptone medium: Slight fluorescent greenish-yellow pigmentation.

Nitrites produced from nitrates.

Ammonia is produced.

Acid and gas from glucose, sucrose, maltose, galactose, fructose, salicin and mannitol. Acid but not gas from glycerol. No acid from lactose, arabinose, xylose, dextrin, inulin, dulcitol or starch.

Hydrogen sulfide produced.

Catalase positive.

Methyl red test positive.

Pathogenic for animals.

Temperature relations: Optimum 37°C. Minimum 20°C. Maximum 45°C.

Aerobic.

Source: From a tumor-like growth on the chuckawalla (*Sauromalus varius*).

Habitat: Causes tumors in lizards.

2. **Serratia anolium** Duran-Reynals and Clausen. (Jour. Bact., *33*, 1937, 369.) From a generic name of lizards, *Anolis*.

Rods: 0.2 to 0.4 by 1.0 to 2.0 microns, occurring singly, in pairs, in clusters and palisades. Pleomorphic, other forms being 4 to 5 microns in length, curved, occasionally club-like, or 10 to 15 microns long and surrounded by a capsular material, or occasionally small and coccus-like. Motile (Duran-Reynals and Clausen) with 1 to 4 peritrichous flagella (Breed). Non-acid-fast. Gram-negative.

Gelatin stab: Rapid growth. Liquefaction infundibuliform. After 6 to 10 days a thick soft pellicle and blackish sediment is formed.

Agar colonies: After 24 hours at 37°C, isolated colonies are low, convex, margin entire or slightly undulate. Colonies translucent, butyrous, glistening, smooth, 1.0 to 2.5 mm in diameter. While some colonies retain their smooth character, others become larger, striated and wrinkled, showing opaque, radiated folds with irregularly crenated edges and a rougher texture. Penetrating acid smell produced.

Agar slant: After 24 hours at 37°C, abundant, confluent, raised, whitish, butyrous, glistening, with entire or undulate edges.

Broth: Moderate growth with uniform turbidity. A pellicle is formed which disintegrates forming a ring on the walls of the tube. Sediment. Faint fluorescent yellowish coloration.

No visible gas in glucose broth (Breed).

Peptone water: After 6 to 10 days marked turbidity, medium darkened, blackish sediment formed.

Litmus milk: Coagulation and digestion. Partial discoloration of the litmus.

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* Prepared by Prof. Robert S. Breed, New York State Experiment Station, Geneva, New York, June, 1946.

Potato: Growth abundant, butyrous, glistening, raised, pinkish.

Indole not formed.

Blood is hemolyzed.

Loeffler's serum: Abundant, glistening growth. Liquefaction.

No H_2S produced.

Ammonia is produced.

Although Duran-Reynals and Clausen report nitrites not produced from nitrates, a retest of their cultures by Breed has shown that nitrites are actively produced from nitrates.

Acid from glucose, fructose, sucrose, mannitol, maltose, galactose and salicin. Dextrin, lactose, inulin, dulcitol, xylose and arabinose slightly attacked or not at all.

Pigment production: Water-soluble pigment produced. Pink coloration best shown on glycerol potato. Reddish coloration best shown in peptone water with 2 per cent glucose, the yellow coloration in glucose broth and the black coloration in the sediment of liquefied gelatin and peptone water. Some non-pigmented strains.

Temperature relations: Grows well at 20°C. Growth more abundant at 37°C. Practically no growth at 10°C. Thermal death point 60°C for 20 minutes.

Aerobic.

Pathogenicity: Pathogenic for amphibians, reptiles and to some extent fish. Lesions are produced in the iguanid lizards (*Anolis equestris* and *Anolis carolinensis*), the gekkonid lizards (*Tarentola mauritanica* and *Hemidactylus brookii*), the garter snake (*Thamnophis butleri*) and the brown snake (*Storeria dekayi*), the musk turtle (*Sternothaerus odoratus*), the toad (*Bufo americanus*), the frog (*Rana pipiens*) and the catfish (*Ameiuras melas*). When the inoculated animal is kept at 37°C, the disease becomes general and usually is fatal. Non-pathogenic for warm-blooded animals (Clausen and Duran-Reynals, Amer. Jour. Path., *13*, 1937, 441).

Source: From tumor-like lesions in Cuban lizards (*Anolis equestris*). Also isolated from iguanid lizards (*Basiliscus vittatus*) from Mexico by Clausen and Duran-Reynals (*loc. cit.*).

Habitat: The cause of a natural, non-fatal, contagious disease of lizards.

3. **Salmonella sp.** (Type Arizona). (*Salmonella sp.*, Dar es salaam Type var. from Arizona, Caldwell and Ryerson, Jour. Inf. Dis., *65*, 1939, 245; *Salmonella arizona* Kauffmann, Acta Path. et Microbiol. Scand., *17*, 1940, or *19*, 1942; Arizona culture, Edwards, Cherry and Bruner, Jour. Inf. Dis., *73*, 1943, 236; *Salmonella arizona* Group, Edwards, Jour. Bact., *49*, 1945, 513.)

Ferments lactose and liquefies gelatin. Antigenic structure: XXXIII: z_4, z_{23}, z_{26}: —.

Source: Isolated by Caldwell and Ryerson (*loc. cit.*) from horned lizards, Gila monsters and chuckawallas. Also pathogenic for guinea pigs and rabbits. Found in snakes by Hinshaw and McNeill (Cornell Vet., *34*, 1944, 248). Also reported by Edwards (*loc. cit.*) from infants.

Habitat: Apparently widely distributed in lizards, snakes, and warm-blooded animals.

TRIBE II. ERWINEAE WINSLOW ET AL.

(Jour. Bact., *5*, 1920, 209.)

Motile rods which normally require organic nitrogen compounds for growth. Produce acid with or without visible gas from a variety of sugars. In some species, the number of carbon compounds attacked is limited and lactose may not be fermented. May or may not liquefy gelatin. May or may not produce nitrites from nitrates. Invade the tissues of living plants and produce dry necrosis, galls, wilts and soft rots. In the latter case, a protopectinase destroys the middle lamellar substance.

There is a single genus.

Genus I. **Erwinia** *Winslow et al.**

(Jour. Bact., *2*, 1917, 560.) Named for Erwin F. Smith, pioneer American plant pathologist.

Characters as for the tribe.

The type species is *Erwinia amylovora* (Burrill) Winslow et al.

Key to the species of genus **Erwinia.**

I. **Pathogens which cause dry necrosis, galls or wilts in plants but not a soft rot (*Erwinia* sensu stricto).
  A. Gas not produced in sugar media.
    1. Gelatin liquefied.
      a. Starch not hydrolyzed.
        b. Nitrites not produced from nitrates.
          1. *Erwinia amylovora.*
        bb. Nitrites produced from nitrates.
          2. *Erwinia milletiae.*
      aa. Starch hydrolyzed.
        b. Nitrites produced from nitrates.
          3. *Erwinia vitivora.*
      aaa. Action on starch not reported.
        b. Nitrites produced from nitrates.
          4. *Erwinia cassavae.*
    2. Gelatin not liquefied.
      a. Starch not hydrolyzed.
        b. Nitrites produced from nitrates.
          5. *Erwinia salicis.*
        bb. Nitrites not produced from nitrates.
          6. *Erwinia tracheiphila.*

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* Completely revised by Prof. F. D. Chester, New York, N. Y., December, 1938; further revision by Prof. Walter H. Burkholder, Cornell University, Ithaca, New York, May, 1945.

** The genus *Erwinia* as defined here is heterogeneous in nature and is composed of at least two distinct groups. The first group constitutes *Erwinia* proper and does not produce visible gas from sugars. Waldee (Iowa State Coll. Jour. Sci., *19*, 1945, 435) in a paper that appeared as this manuscript was ready for the press has suggested that the species in this first group be placed in a separate family *Erwiniaceae*.

II. †Pathogens which normally cause a soft rot in plants (largely belong in the genus *Pectobacterium* Waldee).
- A. Gas produced in sugar media.
  - 1. Gelatin liquefied.
    - a. Nitrites produced from nitrates.
      - b. Hydrogen sulfide produced.
        - 7. *Erwinia betivora.*
        - 8. *Erwinia carnegieana.*
      - bb. Hydrogen sulfide not produced.
        - 9. *Erwinia atroseptica.*
        - 10. *Erwinia carotovora.*
    - aa. Nitrites not produced from nitrates.
      - 11. *Erwinia erivanensis.*
      - 12. *Erwinia flavida.*
  - 2. Gelatin not liquefied.
    - a. Starch hydrolyzed.
      - 13. *Erwinia dissolvens.*
    - aa. Starch not hydrolyzed.
      - 14. *Erwinia nimipressuralis.*
- B. Gas not produced in sugar media.
  - 1. Gelatin liquefied.
    - a. Nitrites produced from nitrates.
      - b. Starch hydrolyzed.
        - 15. *Erwinia ananas.*
        - 16. *Erwinia cytolytica.*
      - bb. Starch not hydrolyzed.
        - c. Acid from lactose.
          - 17. *Erwinia aroideae.*
          - 18. *Erwinia mangiferae.*
        - cc. No acid from lactose.
          - 19. *Erwinia citrimaculans.*
  - 2. Gelatin not liquefied.
    - 20. *Erwinia rhapontici.*
  - 3. Very slow gelatin liquefaction.
    - a. Nitrites not produced from nitrates.
      - 21. *Erwinia lathyri.*
- C. Gas production not reported.
  - 1. Gelatin liquefied.
    - a. Nitrites produced from nitrates.
      - 22. *Erwinia lilii.*

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† The second group of species usually causes soft rots, but includes a few not very typical species. Waldee (*loc. cit.*) has proposed that the species that cause typical soft rot be placed in a new genus, *Pectobacterium*, with *Pectobacterium carotovorum* as the type species. The new genus is retained in the family *Enterobacteriaceae*. Waldee would place the atypical species in other genera, *Erwinia dissolvens* for example being placed in the genus *Aerobacter*. As further comparative studies are needed before such changes can be made with confidence, the older arrangement is allowed to stand in this edition of the MANUAL.

1. **Erwinia amylovora** (Burrill) Winslow et al. (*Micrococcus amylovorus* Burrill, Illinois Indust. Univ., 11th Rept., 1882, 142; American Naturalist, *17*, 1883, 319; *Bacillus amylovorus* Trevisan, I generi e le specie delle Batteriacee, 1889, 19; *Bacterium amylovorus* Chester, Del. Col. Agr. Exp. Sta., 9th Ann. Rept., 1897, 127; *Bacterium amylovorum* Chester, Manual Determ. Bact., 1901, 176; Winslow et al., Jour. Bact., *5*, 1920, 209.) From Latin, starch devouring.

Description mainly from Ark, Phytopath., *27*, 1937, 1.

Rods: 0.7 to 1.0 by 0.9 to 1.5 microns, occurring singly, in pairs and sometimes in short chains. Motile with peritrichous flagella. Gram-negative.

Gelatin colonies: Circular, whitish, amorphous, entire.

Gelatin stab: Slow crateriform liquefaction confined to the upper layer.

Agar colonies: Circular, grayish-white, moist, glistening, irregular margins.

Broth: Turbid, with a thin granular pellicle.

Potato: Growth white, moist, glistening. Medium not softened. No odor. No pigment.

Litmus milk: Coagulated after 3 to 4 days to a pasty condition, with a separation of whey. At first acid, becoming alkaline. Litmus reduced. There is a gradual digestion of the casein.

Blood serum: Growth similar to that on agar. No liquefaction.

Dunham's solution: Rapid growth, but clouding not dense.

Indole not produced.

Nitrites not produced from nitrates.

Most of the strains gave a positive test for ammonia in broth, a few showed only a slight positive test.

Acetylmethylcarbinol produced.

Growth in synthetic media with $(NH_4)_2HPO_4$ as a source of nitrogen and containing different carbohydrates.

Acid without gas from glucose, sucrose, arabinose, mannose, fructose, maltose, cellobiose, raffinose, salicin and amygdalin. Xylose, rhamnose, dulcitol and starch not fermented. Acid production from lactose and galactose variable. Utilizes salts of citric, malic, and hippuric acid. Action on salts of lactic and succinic acids variable. Salts of benzoic, maleic, malonic, oxalic, tartaric and valeric acid are not utilized.

Asparagine fermented with production of alkali. Glycine, valine, isoleucine, glutamic acid, cystine, tyrosine, tryptophane and urea not fermented.

Minimum temperature between 3° and 8°C. Maximum below 37°C.

Optimum pH 6.8. Minimum pH 4.0 to 4.4. Maximum pH 8.8.

Source: From the blossoms, leaves and twigs of the pear and apple.

Habitat: Attacks a large number of species in several tribes of the family *Rosaceae* (Elliott, Manual Bact. Plant Pathogens, 1930, 19).

2. **Erwinia milletiae** (Kawkami and Yoshida) Magrou. (*Bacillus milletiae* Kawkami and Yoshida, Bot. Mag., Tokyo, *34*, 1920, 110; Magrou, in Hauduroy et al., Dict. d. Bact. Path., 1937, 213.) From *Milletia*, a genus named for A. J. Millett.

Rods: 0.4 to 0.6 by 0.9 to 2.5 microns. Motile with peritrichous flagella. Capsules. Gram-negative.

Gelatin: Liquefaction begins after 8 days.

Agar colonies: Circular, flat, smooth, shiny, opaque, waxy yellow. Margins entire.

Broth: Turbid. Heavy precipitate.

Milk: No coagulation. Clears with alkaline reaction.

Conjac: No liquefaction.

Nitrites produced from nitrates.

Acid but no gas from galactose, fructose, lactose, maltose, sucrose and mannitol. No acid from glycerol.

Starch not hydrolyzed.

Growth in 0.2 per cent but not in 0.3 per cent of the following acids in sucrose

peptone broth: Acetic, citric, oxalic and tartaric.

Aerobic.

Grows well at 32°C. Thermal death point, 53°C for 10 min.

Source: From galls on the Japanese wisteria in various localities in Japan.

Habitat: Causes galls on the Japanese wisteria, *Milletia floribunda*.

3. **Erwinia vitivora** (Baccarini) du Plessis. (*Bacillus vitivorus* Baccarini, Bull. della Soc. Bot. Ital., 1894, 235; du Plessis, Dept. Agr. and Forestry Union of S. Africa, Science Bul. 214, 1940, 58.) From Latin, devouring the vine.

Note: Macchiati (Bol. della Soc. Bot., 1897, 156) uses the name *Bacillus baccarinii* for *Bacillus vitivorus*. The description Macchiati gives is not of *Erwinia vitivora* but is evidently that of a saprophyte occurring with the pathogen. He conducted no inoculation experiments. Migula (System der Bakterien, *2*, 1900, 778) gives *Bacillus vitivorus* Bacc. (Malpighia, *6*, 1892, 229) which is an incorrect citation and *Bacillus baccarinii* Macch. 1897, as synonyms of *Bacillus gummis* Comes 1884. It is impossible to determine what this latter species is. Du Plessis (*loc. cit.*) does not believe *Bacillus gummis* is the same as *Erwinia vitivora*.

Rods: 0.74 (0.44 to 1.10) by 1.46 (0.95 to 2.19) microns. Cells sometimes dumbbell-shaped. Motile with peritrichous flagella. Gram-negative. Capsules present.

Gelatin: Liquefaction.

Agar colonies: First punctiform, irregularly circular or lenticular, ultimately circular, raised to pulvinate, glistening, spreading, light to orange-yellow. Agar becomes brown.

Broth: Turbid in 24 hrs. Whitish to lemon yellow pellicle.

Milk: Litmus reduced. Thread-like to spongy curd formed. Yellow whey about curd. Yellow growth on top of plain milk. Medium acid.

Uschinsky's solution: Slowly becomes turbid. Pellicle. Sediment whitish-yellow.

Nitrites produced from nitrates.

Hydrogen sulfide produced.

Acid produced from glucose, fructose, xylose, lactose, sucrose, mannitol and salicin. No acid from raffinose or inulin.

Starch hydrolyzed.

Facultative anaerobe.

Temperature relations: Optimum 25°C. Maximum 35° to 40°C. Minimum 5° to 10°C.

Optimum pH 6.0. Minimum 4.2.

Source: Du Plessis used 5 isolates from various localities in South Africa.

Habitat: Causes a disease of grape vines in South Africa, Italy and France.

4. **Erwinia cassavae** (Handsford) *comb. nov.* (*Bacterium cassavae* Handsford, Ann. Rept. Dept. Agric. Uganda for 1937, II, 1938, 48.) From cassava, the host plant.

Rods: Motile with a few peritrichous flagella. No capsules. Gram-negative.

Gelatin is slowly liquefied.

Agar colonies: Smooth, lens-shaped, edges entire, translucent and of uniform structure. Yellow.

Broth: Turbid with a ring. A yellow precipitate in old cultures.

Milk becomes alkaline. Not cleared.

Nitrates are rapidly reduced to nitrites.

Methyl red test negative. Acetylmethylcarbinol produced (Dowson, Cent. f. Bakt., II Abt., *100*, 1939, 183).

Acid but no gas from glucose, sucrose, maltose and glycerol, but not from lactose.

Facultative anaerobe.

Source: From necrotic lesions on cassava leaves in Uganda.

Habitat: Pathogenic on cassava, *Manihot sp.*

5. **Erwinia salicis** (Day) Chester. (*Bacterium salicis* Day, Oxford For. Mem., *3*, 1924, 14; *Phytomonas salicis*

Magrou, in Hauduroy et al., Dict. d. Bact. Path., 1937, 408; Chester, in Bergey et al., Manual, 5th ed., 1939, 406.) From Latin *salix*, willow; M. L. generic name, *Salix*.

Description from Dowson, Ann. Appl. Biol., *24*, 1937, 542.

Rods: 0.5 to 0.7 by 0.8 to 2.2 microns, occurring singly or in pairs, rarely in chains, with rounded ends. Motile with 5 to 7 long peritrichous flagella. Gram-negative.

Gelatin stab: Beaded growth. No liquefaction.

Infusion agar: Colonies appear slowly, circular, with slightly uneven margins, pale brown by transmitted light, pale gray by reflected.

Infusion agar slants: Growth thin, nearly transparent.

Broth: Moderate, uniform turbidity. No pellicle.

Litmus milk: No change.

Potato: Bright yellow, later fading to pale brown, spreading, abundant, glistening, slimy growth.

Indole not formed.

Nitrites produced from nitrates (Dowson).

Hydrogen sulfide not produced.

Ammonia not produced.

Acetylmethylcarbinol produced. Methyl red test negative (Dowson, Cent. f. Bakt., II Abt., *100*, 1939, 183).

Acid, but no gas, from glucose, galactose, mannose, xylose, maltose, sucrose, raffinose, glycerol, mannitol and salicin. No growth in arabinose, fructose, rhamnose, inulin or dextrin.

No growth in Cohn's solution.

Starch not hydrolyzed.

Temperature relations: Optimum 29° to 30°C. Minimum 5° to 10°C. Maximum 33° to 37°C. Thermal death point 50° to 52°C.

Aerobic, facultative anaerobic.

Source: From the cricket-bat willow (*Salix caerulea*) and from the white willow (*Salix alba*).

Habitat: Causes a water-mark disease of willow in England.

6. **Erwinia tracheiphila** (Erw. Smith) Holland. (*Bacillus tracheiphilus* Erw. Smith, Cent. f. Bakt., II Abt., *1*, 1895, 364; *Bacterium tracheiphilus* Chester, Ann. Rept. Del. Col. Agr. Exp. Sta., *9*, 1897, 72; Smith, see Bacteria in Relation to Plant Diseases, *2*, 1911, 286; Holland, Jour. Bact., *5*, 1920, 215.) From Greek, trachea-loving, i.e., live in fibrovascular bundles.

Rods: 0.5 to 0.7 by 1.2 to 2.5 microns, with rounded ends, occurring singly and in pairs, more rarely in fours. Motile with peritrichous flagella. Capsulated. Gram-negative.

Gelatin colonies: Small, circular, grayish-white, smooth, glistening. Show internal striae by transmitted light.

Gelatin stab: Surface growth thin, spreading, grayish-white. Slight filiform growth in depth. No liquefaction.

Agar colonies: Small, circular, grayish-white, smooth, glistening.

Agar slant: Growth gray, smooth, filiform, moist, glistening.

Broth: Slight turbidity. No ring or pellicle.

Potato: Growth white or color of substratum, smooth, moist, glistening. No action on the starch. Does not soften the middle lamella of potato cells.

Litmus milk: Not coagulated. Reaction unchanged. Litmus not reduced. Not peptonized.

Egg albumen: Not digested.

Blood serum: No liquefaction.

Cohn's solution: No growth.

Uschinsky's solution: Weak growth.

Fermi's solution: Weak growth.

Indole not formed in Dunham's solution.

Nitrites not produced from nitrates.

Ammonia production moderate.

Cannot utilize asparagine, ammonium lactate or tartarate as sources of nitrogen.

Acid without gas from glucose, sucrose and fructose; growth in closed arm. Acid from glycerol. No growth in closed arm with lactose, maltose, dextrin, glycerol or mannitol. No acid from lactose.

Starch not hydrolyzed.

Hydrogen sulfide production feeble.

Growth in broth with 1.0 per cent NaCl retarded; inhibited with 2.0 per cent.

Very sensitive to acid (phenolphthalein).

Temperature relations: Optimum 25° to 30°C. Minimum about 8°C. Maximum 34° to 35°C. Thermal death point 43°C for one hour.

Aerobe and facultative anaerobe.

Source: From various curcurbits.

Habitat: Causes the wilt of cucumber, also affects cantaloupes, muskmelons, pumpkins and squashes.

6a. *Bacillus tracheiphilus* var. *cucumis* E. F. Smith. (An Introduction to Bact. Dis. of Plants, 1920, 135.) Smith states that squash is immune to this variety of *Erwinia tracheiphila*.

7. **Erwinia betivora** (Takimoto) Magrou. (*Bacillus betivorus* Takimoto, Ann. Phyt. Soc. Japan, *2*, 1931, 356; Magrou, in Hauduroy et al., Dict. d. Bact. Path., Paris, 1937, 200). From Latin, devouring the beet.

Rod: Short rods, sometimes filaments. Motile with 2 to 6 peritrichous flagella. Gram-negative.

Gelatin: Liquefaction.

Agar colonies: Circular or amoeboid, homogenous, thin, edges smooth and entire.

Broth: Turbid with pellicle.

Milk: Acid, coagulated.

Nitrites produced from nitrates.

Indole produced.

Hydrogen sulfide produced.

Gas from glucose and sucrose.

Facultative anaerobic.

Optimum temperature 35°C. Minimum 12°C. Maximum 45°C. Thermal death point 50°C for 10 min.

Source: From rot of sugar beets in Korea.

Habitat: Pathogenic on roots of beets. Artificial inoculation of carrots, radishes, potato tubers and tomato fruits gave positive results.

8. **Erwinia carnegieana** Lightle, Standring and Brown. (Phytopath., *32*, 1942, 310.) From the genus *Carnegiea*.

Rods: 1.12 to 1.79 by 1.56 to 2.90 microns. Motile with peritrichous flagella. Capsules. Gram-positive (Lightle et al.). Gram-negative; old cultures show Gram-positive granules in cells (Burkholder).

Gelatin: Slow liquefaction.

Agar colonies: Round, slightly raised, smooth, gray-white, wet-shining, margins entire.

Broth: Abundant growth.

Uschinsky's solution: Turbid, slight ring and sediment.

Milk: Litmus pink to reduced. No curdling.

Nitrites are produced from nitrates.

Hydrogen sulfide is formed (Burkholder).

Acid and gas from glucose, galactose, fructose, maltose, sucrose, raffinose, mannitol and salicin. Acid and gas from lactose and xylose and alkali from sodium tartrate (Burkholder).

Starch not hydrolyzed (Burkholder).

No odor.

Aerobic.

Thermal death point 59°C.

Source: From rotting tissue of the giant cactus (*Carnegiea gigantia*).

Habitat: Pathogenic on the giant cactus, but not on carrots.

9. **Erwinia atroseptica** (van Hall) Jennison. (*Bacillus atrosepticus* van Hall, Inaug. Diss., Amsterdam, 1902, 134; Jennison, Ann. Missouri Bot. Gard., *10*, 1923, 43.) From Latin *ater*, black and *septicus*, putrefying.

Synonyms: Morse (Jour. Agr. Res., *8*, 1917, 79) lists the following synonyms: *Bacillus solanisaprus* Harrison, Cent. f. Bakt., II Abt., *17*, 1906, 34 (*Erwinia solanisapra* Holland, Jour. Bact., *5*, 1920, 222) and *Bacillus melanogenes* Pethybridge and Murphy, Roy. Irish Acad. Proc., *29*, B, No. 1, 1911, 31.

Paine (Jour. Agr. Sci., *8*, pt. 4, 1917,

492) agrees and points out that *Bacillus phytophthorus* Appel is very similar to *Bacillus melanogenes* Pethybridge and Murphy.

Jennison (Ann. Missouri Bot. Gard., *10*, 1923, 1) concurs and adds *Bacillus phytophthorus* Appel, Ber. d. Deut. Bot. Gesell., *20*, 1902, 128 (*nomen nudum*) and K. Biol. Anst. f. Land. u. Forst. Arb., *3*, 1903, 364. (This last reference contains Appel's description which is antedated by van Hall's description of the black leg pathogen.)

Stapp (Arb. d. Biol. Reichs. f. Land- u. Forst., *16*, 1928, 702) besides the above species adds *Bacillus carotovorus* Jones but uses the name *Bacillus phytophthorus* and states that the species contains 5 serological groups.

Description from Jennison (*loc. cit.*).

Rods: 0.6 by 1.5 microns. Motile with a few peritrichous flagella. No capsules. Gram-negative.

Gelatin liquefied.

Agar colonies: Small, round to somewhat irregular and whitish. Surface smooth with a glistening luster.

Broth: Turbid after a few days. Ring and sometimes a light pellicle.

Ammonia production feeble to moderate (Jennison). Ammonia production absent (Morse, *loc. cit.*).

Milk coagulated and acid. A slow peptonization. Litmus reduced.

Indole not formed.

Hydrogen sulfide not produced.

Nitrites are produced from nitrates.

Acid and gas from glucose, galactose, sucrose, lactose, maltose and mannitol. No acid and gas from dextrin and glycerol. Volume of gas is small.

Starch not hydrolyzed.

Cohn's solution: No growth.

Uschinsky's solution: Good growth.

Facultative anerobe (Morse, *loc. cit.*).

Optimum temperature 26°C. Maximum 33°C. Minimum below 5°C (Morse).

Slight growth with 3 per cent salt. None with 4 per cent salt.

Source: From stems of potatoes affected with black-leg.

Habitat: Causes a black rot on stem and tuber of potatoes and other vegetables.

NOTE: Smith (Science, *31*, 1910, 748) regarded *Erwinia solanisapra* and *Erwinia phytophthora* as very closely related. Brooks, Nain and Rhodes (Jour. Path. and Bact., *28*, 1925, 203) held that *Erwinia phytophthora*, *Erwinia solanisapra* and *Erwinia carotovora* are distinct serologically, although identical in cultural characteristics. Berridge (Ann. Appl. Biol., *13*, 1926, 12) claimed from serological tests that *Erwinia phytophthora* and *Erwinia solanisapra* are different yet closely related organisms. Lacey (Ann. Appl. Biol., *13*, 1926, 1) from cultural and serological tests considered *Erwinia phytophthora*, *Erwinia solanisapra* and *Erwinia carotovora* distinct species. Stapp (Arb. a. d. Biol. Reichanstalt f. Landw. u. Forstwirtsch., *16*, 1928, 643) from serological tests places *Erwinia phytophthora* in one serological group and *Erwinia carotovora* in another. Leach (Phytopath., *20*, 1930, 743) found that *Erwinia phytophthora* and *Erwinia carotovora* were indistinguishable in cultural and physiological characteristics, the most consistent difference being the inky black coloration of the tissues infected with the former.

Stapp (in Sorauer, Handb. d. Pflanzenk., 5 Aufl., *2*, 1928, 229) states that it is generally believed that the disease caused by *Bacillus solanincola* Delacroix (Compt. rend. Acad. Sci., Paris, *133*, 1901, 417 and 1030) is the same as stem rot of potato (blackleg).

10. **Erwinia carotovora** (Jones) Holland. (*Bacillus carotovorus* Jones, Cent. f. Bakt., II Abt., 7, 1901, 12; Holland, Jour. Bact., *5*, 1920, 222; *Bacterium carotovorum* Lehmann and Neumann, Bakt. Diag., 7 Aufl., *2*, 1927, 446; *Pectobac-*

terium carotovorum Waldee, Iowa State Coll. Jour. Sci., *19*, 1945, 469.) From Latin, carrot destroying.

Synonyms: Leach (Minnesota Agr. Exp. Sta. Tech. Bull. 76, 1931, 18) lists the following as synonyms:

Bacillus atrosepticus van Hall. (Van Hall, Inaug. Diss., Univ. Amsterdam, 1902, 134; *Erwinia atroseptica* Jennison, Ann. Missouri Bot. Gard., *10*, 1923, 43.)

Bacillus phytophthorus Appel. (Ber. d. deut. Bot. Ges., *20*, 1902, 128; *Erwinia phytophthora* Holland, Jour. Bact., *5*, 1920, 222; *Bacterium phytophthorum* Burgwitz, Phytopath. Bacteria, Leningrad, 1935, 141; *Pectobacterium phytophthorum* Waldee, Iowa State Coll. Jour. Sci., *19*, 1945, 471).

Bacillus solanisaprus Harrison. (Harrison, Cent. f. Bakt., II Abt., *17*, 1907, 34; *Erwinia solanisapra* Holland, Jour. Bact., *5*, 1920, 222.)

Bacillus melanogenes Pethybridge and Murphy. (Roy. Irish Acad., *29*, B, No. 1, 1911, 31.)

Bacillus oleraceae Harrison. (Harrison, Science, *16*, 1902, 152; *Erwinia oleraceae* Holland, Jour. Bact., *5*, 1920, 222.)

Bacillus omnivorus van Hall. (Inaug. Diss., Univ. Amsterdam, 1902, 176.)

Bacillus apivorus Wormald. (Jour. Sci., *6*, 1914, 203.)

Elrod (Bot. Gaz., *103*, 1941, 270) holds that *Erwinia aroideae* is a synonym of *Erwinia carotovora*.

The following also have been considered as possible synonyms of *Erwinia carotovora*:

Bacillus cepivorus Delacroix. (Delacroix, Ann. Inst. Nat. Agron., Sér 2, *5*, 1905, 368; *Bacterium cepivorum* Stapp, in Sorauer, Handb. d. Pflanzenkrankheiten, 5 Aufl., *2*, 1928, 49; *Aplanobacter cepivorus* Elliott, Man. Bact. Plant Path., 1930, 4; *Phytomonas cepivora* Magrou, in Hauduroy et al., Dict. d. Bact. Path., 1937, 344.) Causes a rot of onion bulbs.

Bacillus cypripedii Hori. (Hori, Cent. f. Bakt., II Abt., *31*, 1911, 85; *Erwinia cypripedii* Bergey et al., Manual, 1st ed., 1923, 171.)

Bacillus dahliae Hori and Bokura (Hori and Bokura, Imp. Agr. Expt. Sta. Nishigahara, *38*, 1911, 69; *Erwinia dahliae* Magrou, in Hauduroy et al., Dict. d. Bact. Path., 1937, 205.)

Pseudomonas destructans Potter. (Potter, Proc. Univ. Durham Philos. Soc., 1899, 165 and Proc. Roy. Soc., *67*, 1900, 449; *Bacterium destructans* Nakata, Nakajima and Takimoto, Tech. Rept. Korea Ind. Farm, 1922; *Phytomonas destructans* Bergey et al., Manual, 3rd ed., 1930, 264.) See Paine (Ann. Appl. Biol., *5*, 1918, 64) for a discussion of this species.

Bacillus hyacinthi septicus Heinz. (Heinz, Cent. f. Bakt., *5*, 1889, 539; *Bacillus hyacinthi-septicus* Lehmann and Neumann, Bakt. Diag., 2 Aufl., *2*, 1899, 449; *Bacterium hyacinthi septicus* Chester, Ann. Rept. Del. Col. Agr. Exp. Sta., *9*, 1897, 127; *Bacillus hyacinthi* Migula, Syst. d. Bakt., *2*, 1900, 874; not *Bacillus hyacinthi* Trevisan, I generi e le specie delle Batteriacee, 1899, 19; *Erwinia hyacinthi septica* Magrou, in Hauduroy et al., Dict. d. Bact. Path., 1937, 208.)

Rods: Usually 0.7 to 0.8 by 1.5 to 5.0 microns, occasionally in chains. Stain rather slowly with aniline colors, well with Löffler's methylene blue. No capsules observed. Actively motile with peritrichous flagella. Gram-negative.

Gelatin stab: Rapid surface liquefaction, slower in depth (Jones). Some strains very slow liquefiers.

Agar colonies: After 2 days, circular, convex, smooth, grayish-white, moist, glistening. Margins sharp, entire.

Agar slant: Growth thin, grayish-white, moist, glistening, butyrous. Medium not discolored.

Broth: Turbid, with pellicle and white flocculent sediment. Slow alkaline production.

Litmus milk: After 4 days, coagulated, acid, with separation of whey. Cheesy odor. Litmus reduced. Slightly peptonized.

Potato: Growth thick, creamy-white; medium softened.

Dunham's solution: Feeble persistent turbidity.

Blood serum: Growth much as on agar. Not liquefied.

Uschinsky's solution: Strong turbidity.

Indole production none.

Nitrites produced from nitrates.

Diastase negative.

No H_2S produced or only a trace.

No ammonia produced.

Methyl red positive, Voges-Proskauer negative (Dowson, Cent. f. Bakt., II Abt., *100*, 1939, 183).

Acid and gas from glucose, lactose, sucrose, fructose, raffinose, mannitol, arabinose, xylose, salicin and rhamnose. Acid without gas from glycerol and ethyl alcohol. Butyl alcohol, inulin and starch not fermented.

Facultative anerobe.

Temperature relations: Optimum 25° to 30°C. Minimum 4°C. Maximum 38° to 39°C. Thermal death point 41° to 51°C.

Pathogenesis: Causes a rapid soft rot of roots, rhizomes, fruits and the fleshy stems of a variety of plants.

Source: From rotted carrots.

Habitat: Causes a soft rot in carrot, cabbage, celery, cucumber, egg-plant, iris, muskmelon, hyacinth, onion, parsnip, pepper, potato, radish, tomato, turnip, and other plants.

11. **Erwinia erivanensis** (Kalantarian) Bergey et al. (*Bacterium erivanense* Kalantarian, Cent. f. Bakt., II Abt., *65*, 1925, 298; *Bacillus erivanensis* Stapp, in Sorauer, Handb. d. Pflanzenkr., 5 Aufl., *2*, 1928, 202; Bergey et al., Manual, 3rd ed., 1930, 239.) Derived from Erivan, a city in Armenia.

Whether this organism is to be considered a chromogenic strain or a distinct species is impossible to determine; therefore, it occupies its present position tentatively. It cannot be separated from *Erwinia carotovora* on the basis of chromogenesis since the latter occasionally shows a tendency to the formation of a faint yellowish pigment.

Rods: 0.5 to 0.7 by 1.25 to 2.5 microns. Motile with peritrichous flagella. Gram-negative.

Gelatin colonies: After 3 days at 20°C, circular, 1 to 1.5 mm in diameter, yellowish-white, convex, entire. Microscopically gray with opaque borders and darker patches.

Gelatin stab: Surface growth somewhat umbonate. In 10 to 12 days a slow liquefaction. Intense yellow growth.

Agar colonies: Grayish-white, fatty lustre, turning yellow after several days.

Agar slant: Growth grayish-white, fatty lustre, becoming yellow.

Broth: Strong more or less flocculent turbidity. No surface growth. Little sediment.

Potato: Growth somewhat raised, becoming yellowish.

Milk: Coagulated in 14 days, becoming alkaline, slowly clearing.

Indole is formed.

Nitrites not produced from nitrates.

Acid and gas from glucose, sucrose and mannitol. No gas from lactose and glycerol.

Optimum temperature 20°C.

Source: From cotton plants.

Habitat: Causes a root-rot of cotton (*Gossypium sp.*).

12. **Erwinia flavida** (Fawcett) Magrou. (*Bacillus flavidus* Fawcett, Rev. Indust. y Agrico. de Tucuman, *13*, 1922, 5; Rev. App. Mycology, *2*, 1923, 338; not *Bacillus flavidus* Morse, Jour. Inf. Dis., *11*, 1912, 284; Magrou, in Hauduroy et al., Dict. d. Bact. Path., 1937, 207.) From Latin *flavus*, yellow.

Morphology: Motile with peritrichous flagella. Gram-negative.

Gelatin: Yellow growth. Liquefaction.

Milk: Coagulated.

Potato: Yellow growth.

Indole is formed.

Nitrites not produced from nitrates.

Acid and gas from glucose, lactose and sucrose.

Diastase not formed.

Source: From sugar cane.

Habitat: Causes a soft rot of sugar cane (*Saccharum officinarum*).

NOTE: If this decay is due to a simple organism as stated above, it is probable that it should be considered merely a chromogenic strain of *Erwinia carotovora*.

13. **Erwinia dissolvens** (Rosen) *comb. nov.* (*Pseudomonas dissolvens* Rosen, Phytopath., *12*, 1922, 497; *Phytomonas dissolvens* Rosen, Phytopath., *16*, 1926, 264; *Bacterium dissolvens* Rosen, *ibid.*; *Aplanobacter dissolvens* Rosen, *ibid.*; *Aerobacter dissolvens* Waldee, Iowa State Coll. Jour. Sci., *19*, 1945, 473.) From Latin, dissolving.

Rods: 0.5 to 0.9 by 0.7 to 1.2 microns. Pairs, rarely in chains. Capsules present. First described as motile with a single flagellum; later as non-motile. Gram-negative.

Gelatin: Not liquefied.

Agar colonies: Round, margins entire, white, opaque, glistening, butyrous, emitting a strong odor of decaying vegetables.

Broth: Turbid with heavy surface growth consisting of ring, and floccules or compact slimy masses and streamers. Abundant sediment.

Uschinsky's solution: Good growth, but not viscid.

Litmus milk: Acid, coagulated.

Indole produced.

Nitrites produced from nitrates.

Hydrogen sulfide not produced.

Acid and gas from glucose, galactose, mannitol, sucrose, maltose, lactose and glycerol.

Starch hydrolyzed.

Optimum temperature 30°C.

Good growth in 3 per cent salt. Retarded at 4 per cent.

Source: From rotting corn stalks.

Habitat: Pathogenic in corn plants.

14. **Erwinia nimipressuralis** Carter. (Illinois Nat. Hist. Survey Bull. 23, 1945, 423.) From Latin *nimis*, too much and *pressuralis*, pertaining to pressure.

Rods: Mostly 0.34 to 0.68 by 0.68 to 1.35 microns. Motile with as many as 6 peritrichous flagella. Capsules not observed. Gram-negative.

Gelatin: Not liquefied.

Potato glucose agar: Colonies circular, smooth, whitish-cream, entire, flat to slightly raised and usually opaque. Gas produced when medium is stabbed.

Broth: Abundant with thin pellicle or flocculent surface growth. Sediment scant and viscid. Gas produced in nutrient broth plus glucose was 47 per cent CO_2 and 2.4 per cent hydrogen. CO_2 varied with age of culture, more being produced in young cultures.

Milk: Acid, coagulated. Litmus and bromocresol purple are reduced. Not peptonized.

Nitrites produced from nitrates.

Hydrogen sulfide produced.

Indole not produced.

Acid and gas produced from arabinose, rhamnose, xylose, glucose, fructose, galactose, mannose, lactose, maltose, trehalose, melibiose, cellobiose, mannitol, sorbitol and salicin; no acid or gas from inulin, dextrin or filterpaper; variable results from sucrose, raffinose, melezitose, dulcitol, glycerol and elm sawdust. Pectin is not fermented.

Starch not hydrolyzed.

Methyl red test positive. Acetylmethylcarbinol produced.

Facultative anaerobe.

Optimum temperature 24° to 30°C. Maximum 37°C. Minimum 5°C or lower. Thermal death point 45° to 55°C.

Optimum pH for growth 6.8 to 7.5. Maximum 10.0+. Minimum 4.6.

Source: Five cultures from 5 different trees affected with wet wood.

Habitat: Pathogenic in trunk wood of elms, *Ulmus americana*, *U. pumila*, *U. fulva* and *U. procera*.

15. Erwinia ananas Serrano. (Philippine Jour. Sci., *36*, 1928, 271; *Bacillus ananas* Serrano, *ibid.*; *Bacterium ananas* Burgwitz, Phytopathogenic Bacteria, Leningrad, 1935, 44.) Named for the genus, *Ananas*.

NOTE: Not to be confused with *Pseudomonas* (*Phytomonas*) *ananas* Serrano, Philippine Jour. Sci., *36*, 1928, 271.

Short rods: 0.6 by 0.9 micron, with rounded ends, occurring singly, in pairs and in short chains. Encapsulated. Motile with peritrichous flagella. Gram-negative.

Gelatin stab: Stratiform liquefaction, with a deep chrome-yellow sediment.

Potato glucose agar: After 24 hours, circular, 3 mm in diameter, convex, dense, homogeneous, entire, moist, straw-yellow, mottled, becoming primuline yellow. Plates have a molasses odor. Show two types of colonies, rough and smooth. Rough colonies have crenate margins.

Potato glucose agar slant: Growth straw-yellow, raised, becoming primuline yellow, moist, glistening.

Broth: Turbid, with a straw-colored pellicle and ring.

Glucose broth: Growth sulfur yellow.

Litmus milk: Coagulated, faintly acid, becoming alkaline.

Potato: Copious growth, moist, glistening, spreading, becoming primuline yellow.

Indole not formed.

Blood serum: Moderate growth, slightly raised, mustard yellow to primuline yellow. No liquefaction after 3 months.

Cohn's solution: No growth.

Phenol negative.

Diastase produced.

Nitrites produced from nitrates.

Slight amount of ammonia produced.

Slight amount of H_2S produced.

Small amount of alcohol and aldehyde produced.

No gas from carbohydrates. Acid from glucose, lactose, sucrose, mannitol, raffinose, glycerol, salicin, dextrin, maltose, fructose and mannose. No acid from arabinose, xylose, amygdalin, rhamnose, inositol, inulin, dulcitol, adonitol, asparagine or starch.

Source: From the pineapple (*Ananas sativus*) and sugar-cane (*Saccharum officinarum*).

Habitat: Causes a brown rot of the fruitlets of pineapple.

16. Erwinia cytolytica Chester. (Phytopath., *28*, 1938, 431.) From Latin, cell dissolving.

Rods: 0.6 to 0.7 by 2.5 to 3.5 microns. Singly or in pairs. Gram-negative. Motile with peritrichous flagella.

Gelatin: Slow liquefaction.

Agar colonies: 2 to 3 mm in diameter, round, convex, moist, glistening, grayish-white, watery, translucent. Light brownish-yellow by transmitted light.

Broth: Turbid.

Milk: Coagulated in 5 to 7 days. Slightly acid. Not digested.

Nitrites produced from nitrates.

Indole not formed.

Hydrogen sulfide not formed.

Acetylmethylcarbinol: A slight reaction.

Acid without gas from glucose, lactose, sucrose, raffinose, mannitol, salicin and isodulcitol. No acid from fructose, arabinose, xylose, glycerol and inulin.

Starch hydrolyzed.

Pectin dissolved.

Asparagine, peptone, and ammonia used as nitrogen sources in synthetic medium plus glucose. Potassium nitrate not used.

Optimum temperature 28° to 30°C. Growth at 37°C. Slow growth at 20°C and no growth at 8° to 10°C.

Good growth at pH 6.8 to 7.3. Feeble growth at 5.0. No growth at 4.4.

Aerobic and facultative anaerobic.

Source: Several isolates from diseased dahlias in New York Botanical Garden.

Habitat: Causes a rot of the tuber and stems of dahlias.

17. **Erwinia aroideae** (Townsend) Holland. (*Bacillus aroideae* Townsend, U. S. Dept. Agr., Bur. Plant Ind. Bull. 60, 1904, 40; Holland, Jour. Bact., *5*, 1920, 222; *Bacterium aroideae* Stapp, in Sorauer, Handb. d. Pflanzenkr., 5 Aufl., *2*, 1928, 41; *Pectobacterium aroideae* Waldee, Iowa State Coll. Jour. Sci., *19*, 1945, 472.) From Greek, pertaining to the family *Araceae*.

Probable synonyms: *Erwinia croci* (Mizusawa) Magrou. (*Bacillus croci* Mizusawa, Kanag. Agr. Exp. Sta. Bull. 51, 1921, 1; Ann. Phytopath. Soc. Japan, *1*, 1923, 1; Magrou, in Hauduroy et al., Dict. d. Bact. Path., 1937, 204.) Attacks *Crocus sativus*, also onion.

Erwinia melonis (Giddings) Holland. (*Bacillus melonis* Giddings, Vermont Agr. Exp. Sta. Bull. 148, 1910, 413; Holland, Jour. Bact., *5*, 1920, 222; *Pectobacterium melonis* Waldee, Iowa State Coll. Jour. Sci., *19*, 1945, 473.) E. F. Smith (An Introduction to Bact. Dis. of Plants, 1920, 240) considered *Erwinia melonis* and *Erwinia aroideae* identical. Causes a soft rot of muskmelon.

Erwinia papaveris (Ayyar) Magrou. (*Bacillus papaveris* Ayyar, Mem. Dept. Agr. India, Bact. Ser. 2, 1927, 29; Magrou, in Hauduroy et al., Dict. d. Bact. Path., 1937, 214.) The cause of a soft rot of the garden poppy.

Rods: 0.5 by 2 to 3 microns, with rounded ends, occurring singly, in pairs and in fours, also in chains under certain conditions. Motile with peritrichous flagella. No capsules. Gram-negative.

Gelatin stab: Narrow infundibuliform liquefaction.

Agar colonies: Circular to amoeboid, white, glistening. Borders sharp. Granular structure.

Agar slant: Growth white to grayish-white, moist, glistening. Medium not discolored.

Broth: Turbid.

Potato: Growth whitish, with tinge of yellow. Medium grayed.

Litmus milk: Coagulated, acid, with separation of whey, not peptonized. Litmus reduced.

Indole not formed.

Nitrites produced from nitrates.

Acetylmethylcarbinol produced. Methyl red negative (Dowson, Cent. f. Bakt., II Abt., *100*, 1939, 183).

Acid without gas from glucose, lactose, sucrose, maltose, mannitol, glycerol, fructose, raffinose, arabinose and xylose. Growth in closed arm.

Diastase slight.

Hydrogen sulfide produced.

Uschinsky's solution: Good growth.

No growth in nitrogen. Growth feeble in H_2 and CO_2.

Temperature relations: Optimum 35°C. Minimum 6°C. Maximum 41°C. Thermal death point 50°C for 10 minutes.

Facultative anaerobe.

Differential characters: See *Erwinia carotovora*. Massey (Phytopath., *14*, 1924, 460) considered *Erwinia aroideae* and *Erwinia carotovora* distinct species, though closely related. Link and Taliaferro (Bot. Gazette, *85*, 1928, 198) found them distinct serologically. Dowson (Ann. Appl. Biol., *28*, 1941, 102) differentiated them on their action on maltose and xylose.

Source: From rotted calla lily.

Habitat: Causes a soft rot of calla. Affects raw potato, egg-plant, cauliflower, radish, cucumber, cabbage, parsnip, turnip, salsify, tomato (ripe and green).

18. **Erwinia mangiferae** (Doidge) Bergey et al. (*Bacillus mangiferae* Doidge, Ann. Appl. Biol., *2*, 1915, 1; Bergey et al., Manual, 1st ed., 1923, 173.) Named for the genus, *Mangifera*.

Rods: 0.6 by 1.5 microns, occurring singly and in chains, with rounded ends. Encapsulated. Motile with peritrichous flagella. Gram-negative.

Gelatin stab: Medium liquefied in 10 to 17 days. Growth yellow.

Agar colonies: Glistening, yellowish, undulate borders.

Agar slant: Growth yellow, glistening.

Broth: Turbid, with yellow ring.

Litmus milk: Slow coagulation at 37°C. Slight acidity. Casein slowly dissolved. Litmus reduced.

Potato: Growth spreading, glistening, yellowish. Medium not discolored.

Indole formed in peptone solution. Phenol negative.

Nitrites produced from nitrates.

No H_2S produced.

No ammonia in broth.

Feeble acid production without gas from glucose, lactose, sucrose, fructose and glycerol. No growth in closed arm with lactose and glycerol; more or less growth in closed arm with glucose, sucrose, fructose, maltose, raffinose and mannitol.

Diastase not formed.

Produces an enzyme capable of dissolving the middle lamella but without action on cellulose.

Cohn's solution: Slight turbidity.

Uschinsky's solution: No growth.

Fermis' solution with starch jelly: No growth.

Pigment insoluble in water, alcohol, ether, chloroform or dilute acids.

Temperature relations: Optimum 30°C. Minimum 5° to 6°C. Maximum 45°C. Thermal death point 60°C.

Source: From the mango in Africa.

Habitat: Causes a disease of the mango (*Mangifera indica*).

19. **Erwinia citrimaculans** (Doidge) Magrou. (*Bacillus citrimaculans* Doidge, Ann. Appl. Biol., *3*, 1917, 53; *Bacterium citrimaculans* Burgwitz, Phytopath. Bacteria, Leningrad, 1935, 154; Magrou, in Hauduroy et al., Dict. d. Bact. Path., 1937, 203.) From the genus *Citrus* and Latin *maculans*, spotting.

Rods: 0.45 to 0.7 by 0.8 to 3.2 microns. Motile with peritrichous flagella. Conspicuous capsule present. Gram-positive. Dowson thinks this species Gram-negative (Cent. f. Bakt., II Abt., *100*, 1939, 184).

Gelatin: Liquefied.

Agar colonies: Subcircular, yellow, with dense grumose centers.

Broth: Turbid, with pellicle and sediment.

Milk: Coagulated, with precipitation of casein and extrusion of whey. Not peptonized. Litmus gradually reduced.

Blood serum: Not liquefied.

Indole is formed.

Nitrites produced from nitrates with evolution of gas.

Ammonia produced in broth.

Acid without visible gas from glucose, sucrose, fructose, galactose, maltose and mannitol. No acid from lactose, glycerol, dextrin or starch.

Diastase not produced.

Cohn's solution: No growth.

Uschinsky's solution: Growth present.

No growth in broth over chloroform.

Methylene blue and neutral red reduced.

Pigment insoluble in water, alcohol, ether, chloroform, carbon bisulfide, dilute acid or alkalis.

A turbid growth is produced in 10 per cent salt.

Temperature relations: Optimum 35°C. Maximum 43°C. Thermal death point 62°C for 10 minutes.

Facultative anaerobe.

Source: From diseased lemons and oranges.

Habitat: Causes a spot disease of citrus. In nature attacks lemons, oranges, naartjes and has also been successfully inoculated into limes, shaddock, grapefruit and citron. Seville oranges are resistant.

20. **Erwinia rhapontici** (Millard) *comb. nov.* (*Phytomonas rhapontica* Millard, Univ. Leeds and Yorkshire Council for Agr. Ed. Bul. 134, 1924, 111; *Bacterium rhaponticum* Millard, *ibid.*; *Aplanobacter rhaponticum* Elliott, Man. Bact. Plant Path., 1930, 12.) From Greek *Rha pontic*, rhubarb of Pontus, a province of Asia Minor; M. L. *Rheum rhaponticum*.

Description from Metcalfe, Ann. of Appl. Biol., 27, 1940, 502, where he suggests it belongs in *Erwinia*.

Rods: 0.5 to 0.8 by 1.2 to 1.5 microns. Motile with 3 to 7 peritrichous flagella. Gram-negative.

Gelatin stab: Beaded growth. No liquefaction.

Infusion agar: Colonies circular, convex, smooth, glistening, translucent, with margins entire, 2 to 3 mm in diameter in 48 hours at 25°C.

Rhubarb agar: Colonies slightly larger, often with a yellowish tinge.

Tryptophane broth: Turbid with fragile pellicle, a slight rim and slight flocculent deposit.

Milk: Acid in 3 to 4 days with or without slight curd separation. No clotting.

Indole not produced.

Nitrites formed from nitrates.

Acetylmethylcarbinol produced.

No hydrogen sulfide produced.

Cohn's solution: Moderate growth.

Acid but no gas from arabinose, xylose, glucose, galactose, fructose, mannose, lactose, maltose, sucrose, mannitol, glycerol and salicin.

Growth in citrate solution.

Starch not hydrolyzed.

Chromogenesis: Water-soluble pinkish pigment in various media.

Growth from 0°C to 37°C and possibly higher.

Distinctive characters: Differs from *Erwinia aroideae* in that it does not liquify gelatin nor clot milk and is chromogenic. It also has a limited host range.

Source: From rotting rhubarb crowns. Metcalfe used 6 isolates from various sources in describing the pathogen.

Habitat: Causes a crown-rot of rhubarb.

21. **Erwinia lathyri** (Manns and Taubenhaus) Holland. (*Bacillus lathyri* Manns and Taubenhaus, Gardener's Chronicle, *53*, 1913, 215; Manns, Delaware Agr. Exp. Sta., Bul. 108, 1915, 23; Holland, Jour. Bact., *5*, 1920 218; *Bacterium lathyri* Burgwitz, Phytopath. Bacteria, Leningrad, 1935, 76.) From the genus *Lathyrus*.

Rods: After 24 hours at 25° to 28°C, 0.6 to 0.85 by 0.75 to 1.5 microns, with rounded ends. No capsules. Motile with peritrichous flagella. Gram-negative.

Gelatin colonies: After 8 days, circular, slightly convex, edges smooth. Liquefaction too slow to show on plate.

Gelatin stab: Growth best at surface. Line of stab filiform. Liquefaction slow, fairly well begun in four weeks, complete in three months.

Agar colonies: After 24 hours, yellow, stellate to amoeboid, smooth, glistening, slightly raised, entire. Centers granular, yellow.

Agar slant: Growth filiform, slightly convex, smooth, glistening, opaque, butyrous, light to deep yellow. Odor absent.

Broth: Strong turbidity in 24 hours, little or no pellicle. Sediment scant.

Litmus milk: Slow increase of acidity, not always sufficient to cause coagulation. Digestion of casein slow and variable.

Potato: Growth rapid, filiform, slightly convex, smooth, glistening, butyrous to slightly viscid. Light to deep yellow. Medium not discolored.

Indole is formed.

Cohn's solution: No growth.

Uschinsky's solution: Rapid growth, sometimes a pellicle. Fluid viscid.

Asparagine solution: Good growth.

Nitrites are not produced from nitrates.

Ammonia produced in broth and asparagine solution.

No gas from carbohydrates. Acid from glucose, lactose, sucrose, mannitol and glycerol. No growth in closed arm.

Diastase not formed or extremely weak.

Growth in broth over chloroform absent.

Growth inhibited by 4 per cent NaCl.

Temperature relations: Optimum 28°

to 30°C. Thermal death point 46° to 48°C for 10 minutes.

Aerobic.

Source: From sweet peas.

Habitat: Stated to be pathogenic for sweet pea (*Lathyrus odoratus*) and other legumes. Considered by many to be a saprophyte.

22. **Erwinia lilii** (Uyeda) Magrou. (*Bacillus lilii* Uyeda, by Bokura, Ann. Phytopath. Soc. Japan, *1* (2), 1919, 36; Magrou, in Hauduroy et al., Dict. d. Bact. Path., 1937, 210.) From Latin *lilium*, a name taken from the Greek but derived from the Celtic word *li* meaning white; M. L., generic name, *Lilium*.

Translated by Marion Okimoto.

Rods: 0.6 to 0.7 by 0.8 to 1.0 micron. No capsules. Motile with 6 to 8 peritrichous flagella. Gram-positive(?).

Gelatin: Liquefaction.

Gelatin plate: Colonies after 2 days, round and smooth with grayish surface.

Broth: Alkaline, ammonia produced.

Milk: Curd formation.

Indole produced.

Nitrites produced from nitrates.

Hydrogen sulfide produced.

Sugar medium changes to a brown color.

Conjac not utilized.

Aerobic, facultative.

Optimum temperature 32° to 34°C. Killed in 3 min. at 50°C. Resists—20°C for 30 min.

Source: From brown spots on lily bulbs in Japan.

Habitat: Causes a disease of lily bulbs and leaves.

Appendix: The following additional species are found in the literature. Many are incompletely described.

Bacillus brassicaevorus Delacroix. (Compt. rend. Acad. Sci., Paris, *140*, 1905, 1356.) Presumably causes a rot of cabbage.

Bacillus farnetianus Pavarino. (Atti R. Accad. Naz. Lincei Rend. Cl. Sci. Fis., Mat. e Nat., *20*, 1911, 233.)

Bacillus putrefaciens putridus Delacroix. (Ann. Inst. Nat. Agron., *5*, 1906, 154.) Pathogenic for tobacco.

Bacillus solaniperda Migula. (Syst. d. Bakt., *2*, 1900, 573; *Bacillus krameri* Chester, Man. Determ. Bact., 1901, 282.) Causes a soft rot of potato.

Bacillus spieckermanni Jaczewski. (Elliott, Bacterial Plant Diseases, 1935, 67.) Name applied to a species described by Spieckermann (Landw. Jahrb., *31*, 1902, 155) but left unnamed.

Bacillus tabacivorus Delacroix. (Ann. Inst. Nat. Agron., *5*, 1906, 266.) Said to cause collar rot of tobacco.

Bacillus tabificans Delacroix. (Compt. rend. Acad. Sci., Paris, *137*, 1903, 871.) Said to cause spotting of tobacco leaves.

Bacterium loehnisi Kalantarian. (Kalantarian, Cent. f. Bakt., II Abt., *65*, 1925, 301; *Phytomonas loehnisii* Bergey et al., Manual, 3rd ed., 1930, 276.) From diseased cotton plants. Peritrichous.

Bacterium lycopersici Burgwitz. (Ztschr. f. Pflanzenkr., *34*, 1924, 304.) From a blossom end rot of tomato.

Erwinia alliariae (Omori) Magrou. (*Bacillus alliariae* Omori, Official Gaz. of Japan, *11*, 1896, No. 3758; Magrou, in Hauduroy et al., Dict. d. Bact. Path., 1937, 195.) Causes a root rot of horseradish.

Erwinia araliavora (Uyeda) Magrou. (*Bacillus araliavorus* Uyeda, Bull. Imp. Agr. Exp. Sta. Tokyo, *35*, 1909, 61; Magrou, in Hauduroy et al., Dict. d. Bact. Path., 1937, 197.) Causes a root rot of ginseng.

Erwinia asteracearum (Pavarino) Magrou. (*Bacillus asteracearum* Paravino, Atti R. Accad. Naz. Lincei Rend. Cl. Sci. Fis., Mat. e Nat., Ser. 5, *21*, 1912, 544; Magrou, in Hauduroy et al., Dict. d. Bact. Path., 1937, 199.) Pathogenic for the aster (*Aster chinensis*).

Erwinia bussei (Migula) Magrou. (Bacillus B, Busse, Ztschr. f. Pflanzenkr., 7, 1897, 74; *Bacillus bussei* Migula, Syst. d. Bakt., *2*, 1900, 779; *Bacillus betae* Lehmann and Neumann, Bakt. Diag., 4 Aufl., *2*, 1907, 599; not *Bacillus betae* Migula, Syst. d. Bakt., *2*, 1900, 779; Magrou, in

Hauduroy et al., Dict. d. Bact. Path., 1937, 200.) Pathogenic for the sugar beet.

Erwinia cacticida (Johnston and Hitchcock) Magrou. (*B. cacticidus* Johnston and Hitchcock, Trans. and Proc. Roy. Soc. South Australia, *47*, 1923, 162; Magrou, in Hauduroy et al., Dict. d. Bact. Path., 1937, 201.) Causes a rot of cactus.

Erwinia edgeworthiae (Hori and Bokura) Magrou. (*Bacillus edgeworthiae* Hori and Bokura, Ideta Arata, Supplement to Handbook of the Plant Diseases of Japan, *1*, 1925, 32; Magrou, in Hauduroy et al., Dict. d. Bact. Path., 1937, 206.) Pathogenic on *Edgeworthia chrysantha*, an oriental shrub.

Erwinia ixiae (Severini) Magrou. (*Bacillus ixiae* Severini, Annali di Botanica, Rome, *11*, 1913, 413; Magrou, in Hauduroy et al., Dict. d. Bact. Path., 1937, 208.) Pathogenic on gladiolus and other bulbs.

Erwinia nelliae (Welles) Magrou. (*Bacillus nelliae* Welles, Philippine Jour. Sci., *20*, 1922, 279; Magrou, in Hauduroy et al., Dict. d. Bact. Path., 1937, 213.)

Erwinia papayae (Rant) Magrou. (*Bacillus papayae* Rant, Cent. f. Bakt., II Abt., *84*, 1931, 483; Magrou, in Hauduroy et al., Dict. d. Bact. Path., 1937, 214.) Pathogenic on papaya.

Erwinia sacchari Roldan. (Philippine Agric., *20*, 1931, 256; *Bacillus saccharum* Roldan, *idem*; not *Bacillus sacchari* Janse, Mededeel. uit's Lands. Plantentuin, *9*, 1891, 1.)

Erwinia scabiegena (von Faber) Magrou. (*Bacterium scabiegenum* von Faber, Arb. Kais. Biol. Anst. f. Land. u. Forstw., *5*, 1907, 347; *Bacillus scabiegenus* Stapp, in Sorauer, Handb. d. Pflanzenkr., 5 Aufl., *2*, 1928, 103; Magrou, in Hauduroy et al., Dict. d. Bact. Path., 1937, 217.) Pathogenic for the beet (*Beta vulgaris*).

Erwinia serbinowi (Potebnia) Magrou. (*Bacterium beticola* Serbinow, Zhurnal Bolezni Rastenii, *7*, 1913, 237; not *Bacterium beticola* Smith, Brown and Townsend, Bur. Plant Ind., U. S. Dept. Agr., Bul. 213, 1911, 194; *Bacterium serbinowi* Potebnia, Kharkov Prov. Agr. Exp. Sta., *1*, 1915, 1; *Bacillus beticola* Stapp, in Sorauer, Handb. d. Pflanzenkr., 5 Aufl., *2*, 1928, 93; *Bacillus serbinowi* Elliott, Man. of Bact. Plant Pathogens, 1930, 75; Magrou, in Hauduroy et al., Dict. d. Bact. Path., 1937, 217.) Pathogenic for the sugar beet.

Erwinia uvae (Kruse) Magrou. (Bacillo della bacterosidei grappoli della vite, Cugini and Macchiati, Le Stazione sperimentali ital., *20*, 1891, 579; *Bacillus uvae* Kruse, in Flügge, Die Mikroorganismen, 3 Aufl., *2*, 1896, 329; *Bacterium uvae* Chester, Ann. Rept. Del. Agr. Exp. Sta., *9*, 1897, 53 and 127; Magrou, in Hauduroy et al., Dict. d. Bact. Path., 1937, 220.) Pathogenic for the grape.

Erwinia vitavora du Plessis syn. *Clostridium baccarinii* Bergey et al., Manual, 1st ed., 1923, 328.

TRIBE III. SERRATEAE BERGEY, BREED AND MURRAY

(Preprint, Manual, 5th ed., October, 1938, vi.)

Small, aerobic rods, usually producing a bright red or pink pigment on agar and gelatin. There is a single genus.

Genus I. Serratia *Bizio* emend. *Breed and Breed.**

(Bizio, Biblioteca italiana o sia Giornale de lettera, scienze e arti, *30*, 1823, 288; *Zaogalactina* Sette, Sull'arrossimento straordinario di alcune sostanze alimentose osservato nella provincia di Padova l'anno 1819. Venezia, 1824, 51; *Coccobacterium* Schmidt and Weis, Die Bakterien, 1902, 10; *Erythrobacillus* Fortineau, Compt. rend. Soc. Biol., Paris, *58*, 1905, 104; *Dicrobactrum* Enderlein, Sitzber. Gesell. Naturf. Freunde, Berlin, 1917, 309; Breed and Breed, Cent. f. Bakt., II Abt., *71*, 1927, 435.) Named for Serafino Serrati, the Italian physicist who invented a steam boat at Florence before 1787.

Small, aerobic, rapidly liquefying, nitrate reducing, Gram-negative, peritrichous rods which produce characteristic red pigments. White to rose-red strains that lack brilliant colors are common. Coagulate and digest milk. Liquefy blood serum. Typical species produce CO_2 and frequently H_2 from glucose and other sugars; also acetic, formic, succinic and lactic acids, acetylmethylcarbinol and 2,3 butylene glycol. Saprophytic on decaying plant or even animal materials.

The type species is *Serratia marcescens* Bizio.

Key to the species of genus Serratia.

I. Pigment not especially water-soluble, readily soluble in alcohol.
  A. No visible gas from glucose.
    1. Inconspicuous pellicle, if any, on plain gelatin.
      1. *Serratia marcescens.*
    2. Brilliant orange-red pellicle on plain gelatin.
      2. *Serratia indica.*
  B. Produce enough H_2 with the CO_2 from glucose to show gas in fermentation tubes.
    1. Acetylmethylcarbinol produced.
      3. *Serratia plymuthicum.*
    2. Acetylmethylcarbinol not produced.
      4. *Serratia kilensis.*
II. Pigment soluble in water and alcohol.
      5. *Serratia piscatorum.*

1. **Serratia marcescens** Bizio. (Polenta porporina, Biblioteca italiana, *30*, 1823, 288.) From Latin, dissolving into a fluid or viscous matter.

Synonyms: *Zoagalactina imetrofa* Sette, Memoria storico-naturale sull' arrossimento straordinario di alcune sostanze alimentose. Venezia, 8°, 1824, 51; *Protococcus imetrophus* Meneghini, 1838, see Trevisan, Rend. R. Inst. Lomb.

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* Revised by Prof. Robert S. Breed, New York State Experiment Station, Geneva, New York, Nov., 1937; further revision by Prof. Robert S. Breed, Nov., 1945.

di Sci. e Let., Ser. 2, *20*, 1887, 797; *Monas prodigiosa* Ehrenberg, Bericht ü. d. z. Bekanntmachung geeigneten Verhandlungen d. Kgl. preuss. Acad. d. Wissenschaften, 1849, 354; *Palmella prodigiosa* Montague, Bul. Soc. nat. et cent. d. agric. Paris, Sér. 2, *7*, 1853, 527; *Micraloa prodigiosa* Zanardini, 1863, see Trevisan, *loc. cit.*, 1887, 799; *Bacteridium prodigiosum* Schroeter, in Cohn, Beiträge z. Biol. d. Pflanzen, *1*, Heft 2, 1872, 109; *Micrococcus prodigiosus* Cohn, *ibid.*, 127; *Bacillus prodigiosus* Flügge, Die Mikroorganismen, 1886, 284; *Bacillus imetrophus* Trevisan, *loc. cit.*, 797; *Bacillus marcescens* De Toni and Trevisan, in Saccardo, Sylloge Fungorum, *8*, 1889, 976; *Bacterium prodigiosum* Lehmann and Neumann, Bakt. Diag., 1 Aufl., *2*, 1896, 259; *Liquidobacterium prodigiosum* Orla-Jensen, Cent. f. Bakt., II Abt., *22*, 1909, 339; *Erythrobacillus prodigiosus* Winslow et al., Jour. Bact., *5*, 1920, 209; *Dicrobactrum prodigiosum* Enderlein, Bakterien Cyclogenie, 1925, 279; *Salmonella marcescens* and *Salmonella prodigiosa* Pribram, Jour. Bact., *18*, 1929, 384; *Chromobacterium prodigiosum* Topley and Wilson, Principles of Bacteriology, *1*, 1931, 402.

Description largely taken from Breed and Breed, Jour. Bact., *9*, 1924, 545.

Short rods, sometimes almost spherical: 0.5 by 0.5 to 1.0 micron, occurring singly and occasionally in chains of 5 or 6 elements. Motile, with four peritrichous flagella. Eight to ten flagella on cells grown at 20° to 25°C (De Rossi, Rivista d'Igiene, *14*, 1903, 000). Gram-negative.

Gelatin colonies: Thin, slightly granular, gray becoming red, circular, with slightly undulate margin. Liquefy the medium rather quickly.

Gelatin stab: Infundibuliform liquefaction. Sediment in liquefied medium usually red on top, white in the depth.

Agar colonies: Circular, thin, granular, white becoming red. R and S colonies with mucoid variants (Reed, Jour. Bact., *34*, 1937, 255).

Agar slant: White, smooth, moist layer, taking on an orange-red to fuchsin color in three or four days, sometimes with metallic luster.

Broth: Turbid, may form a red ring at surface or slight pellicle, and gray sediment.

Litmus milk: Acid reaction with soft coagulum. A red surface growth develops. Little or no digestion takes place.

Potato: At first a white line appears, which rapidly turns red. The growth is luxuriant and frequently shows a metallic luster.

Produces acetic, formic, succinic and levolactic acid, ethyl alcohol, acetylmethylcarbinol, 2,3 butylene glycol, CO_2 and a trace of H_2 from glucose (Pederson and Breed, Jour. Bact., *16*, 1928, 183).

Grows poorly or not at all in distilled water containing urea, potassium chloride and glucose.

Indole not produced.

Nitrites produced from nitrates.

Formation of H_2S: Produced from cysteine, cystine or organic sulfur compounds containing either of these molecules. Produced from sulfur but not from sulfites, sulfates or thiosulfates (Tarr, Biochem. Jour., *27*, 1933, 1869; *28*, 1934, 192).

Acetylmethylcarbinol is produced (Breed).

Pigment soluble in alcohol, ether, chloroform, benzol and carbon bisulfide (Schneider, Arb. Bakt. Hochsch. Karlsruhe, *1*, 1894, 210). Pigment may diffuse through the agar, i.e., shows solubility in water where strains are very deeply pigmented (Breed). Pigment not formed at 35°C.

Sodium formate broth (Stark and England, Jour. Bact., *29*, 1935, 26): Cultures do not produce visible gas (Breed).

Odor of trimethylamine is produced.

Aerobic, facultative.

Optimum temperature 25° to 30°C. No growth at 37°C.

Source: Described by Bizio (*loc. cit.*) and Sette (*loc. cit.*) from growth on corn meal mush (polenta).

Habitat: Water, soil, milk, foods, silk worms and other insects.

2. **Serratia indica** (Eisenberg) Bergey et al. (*Bacillus indicus* Eisenberg, Bakt. Diag., 1 Aufl., 1886, 1; *Bacillus indicus ruber* Flügge, Die Mikroorganismen, 2 Aufl., 1886, 285; *Micrococcus indicus* Koch, Berichte ueber die Reise zur Erforschung der Cholera, 1887; *Bacillus ruber indicus* Kruse, in Flügge, Die Mikroorganismen, 3 Aufl., *2*, 1896, 302; *Bacterium ruber indicus* Chester, Ann. Rept. Del. Col. Agr. Exp. Sta., *9*, 1897, 112; *Erythrobacillus indicus* Holland, Jour. Bact., *5*, 1920, 218; Bergey et al., Manual, 1st ed., 1923, 88; Breed and Breed, Jour. of Bact., *11*, 1926, 76; *Chromobacterium indicum* Topley and Wilson, Princ. Bact. and Immun., *1*, 1931, 402.) From Latin *indicus*, of India.

Small rods: 0.5 by 1.0 to 1.5 microns. Motile with four peritrichous flagella. Gram-negative.

Gelatin colonies: Resemble those of *Serratia marcescens*.

Gelatin stab: Liquefied rather quickly. Brilliant orange-red pellicle on plain gelatin.

Agar colonies: Pink, with slightly serrate margin, spreading, with green irridescence.

Agar slant: Luxuriant, dirty-white layer. Pigment produced best in alkaline media.

Broth: Turbid, with white sediment.

Litmus milk: Acid and coagulated. Digestion complete in 10 days.

Potato: Luxuriant growth with or without pigment formation.

Produces same products (except H_2) from glucose as does *Serratia marcescens* (Pederson and Breed, Jour. Bact., *16*, 1928, 183).

Indole not produced.

Nitrites produced from nitrates.

Growth with pigment production in distilled water containing urea, potassium chloride and glucose.

Blood serum liquefied.

Odor of trimethylamine.

Sodium formate broth: Cultures do not produce visible gas (Breed).

Pathogenic for laboratory animals.

Acetylmethylcarbinol is produced (Breed).

Aerobic, facultative.

Optimum temperature 25° to 35°C. No growth at 37°C.

Cultures of this organism lose their ability to produce the orange-red pellicle on gelatin and then become practically indistinguishable from cultures of *Serratia marcescens*. This would indicate that this so-called species is a rough strain of the former species (Breed). See Reed (Jour. Bact., *34*, 1937, 255) for a discussion of dissociation phenomena in this genus.

Source: Isolated from alimentary tract of a Java ape in India; also from milk can from Ithaca, N. Y.

Habitat: Presumably widely distributed.

Apparently the following non-gelatin liquefying strain belongs with this species. Subcultures that are claimed to be derived from the original now liquefy gelatin.

2a. *Serratia miquelii* Bergey et al. (Named *Bacillus ruber* by Miquel and described in a letter to Hefferan, Cent. f. Bakt., II Abt., *11*, 1903, 402; *Erythrobacillus ruber* Holland, Jour. Bact., *5*, 1920, 223; Bergey et al., Manual, 1st ed., 1923, 95.)

Isolated from water by Miquel.

3. **Serratia plymuthicum** (Lehmann and Neumann) Bergey et al. (Roter

Bacillus aus Plymouth, Fischer, Zeitschr. f. Hyg., *2*, 1887, 74; *Bacterium plymuthicum* Lehmann and Neumann, Bakt. Diag., 1 Aufl., *2*, 1896, 264; *Bacillus plymouthensis* Migula, Syst. d. Bakt., *2*, 1900, 849; *Erythrobacillus plymouthensis* Holland, Jour. Bact., *5*, 1920, 220; Bergey et al., Manual, 1st ed., 1923, 88.) Latinized from Plymouth, England.

Distinct rods: 0.6 by 1.5 to 2.0 microns with rounded ends, occurring singly and in short chains. Motile with peritrichous flagella. Gram-negative.

Gelatin colonies: Like *Serratia marcescens*. Original culture mucoid.

Gelatin stab: Crateriform liquefaction. Liquefaction as in *Serratia marcescens*.

Agar colonies: Like mucoid varieties of *Serratia marcescens*.

Agar slant: Sometimes show metallic luster. Pigment as in *Serratia marcescens*.

Broth: Like *Serratia marcescens*.

Litmus milk: Acid and coagulated.

Potato: Growth violet pink, with or without metallic luster.

Gas from glucose, lactose and sucrose, 70 to 80 per cent of it CO_2. Remainder is H_2. Gas is also produced in asparagine solutions.

Strong fecal odor produced.

Blood serum liquefied.

Acetylmethylcarbinol is produced (Breed).

Sodium formate broth: Cultures produce abundant gas (Breed).

Pigment soluble in alcohol, ether and sometimes water.

Aerobic, facultative.

Optimum temperature 30°C.

Source: From water supply of Plymouth, England.

Habitat: Water and various foods.

4. **Serratia kilensis** (Lehmann and Neumann) Bergey et al. (Bacterium h, Breunig, Inaug. Diss., Kiel, 1888; *Bacillus ruber balticus* Kruse, in Flügge, Die Mikroorganismen, 3 Aufl., *2*, 1896, 303; *Bacterium kiliense* Lehmann and Neumann, Bakt. Diag., 1 Aufl., *2*, 1896, 263; *Bacterium ruber balticus* Chester, Ann. Rept. Del. Col. Agr. Exp. Sta., *9*, 1897, 142; *Bacillus kiliensis* Migula, Syst. d. Bakt., *2*, 1900, 847; *Erythrobacillus kiliensis* Holland, Jour. Bact., *5*, 1920, 218; Bergey et al., Manual, 1st ed., 1923, 90; *Chromobacterium kielense* Topley and Wilson, Princip. Bact. and Immun., *1*, 1931, 400.) From Kiel, a city on the Baltic Sea.

Description taken from Kruse (*loc. cit.*) and Bergey et al. (*loc. cit.*).

Slender rods: 0.7 to 0.8 by 2.5 to 5.0 microns, occurring singly. Motile with four peritrichous flagella. Gram-negative.

Deep gelatin colonies: Bright yellow. Gelatin liquefied slowly, usually becoming rose-red.

Glucose gelatin stab: Rapid liquefaction. Occasional gas bubbles (Breed).

Agar colonies: Small, red becoming magenta, smooth.

Agar slant: Bright red becoming darker in old cultures.

Agar stab: Turbid strongly pigmented water of condensation.

Broth: Turbid. Usually reddened.

Litmus milk: Acid; at 20°C, coagulated slowly and pigment produced; at 35°C, coagulated rapidly and no pigment produced.

Potato: Slight red growth, becoming luxuriant and darker.

Indole not formed.

Nitrites and free nitrogen produced from nitrates.

Blood serum liquefied.

Acid and gas from carbohydrates (Lehmann and Neumann, *loc. cit.*). Gas from glucose, lactose and sucrose, 20 to 30 per cent of it CO_2 (Bergey). Inactive lactic acid produced and not more than a trace of acetylmethylcarbinol or 2, 3 butylene glycol (Pederson and Breed, Jour. Bact., *16*, 1928, 183).

Sodium formate broth: Gas produced (Breed).

Acetylmethylcarbinol not produced by the Král culture (Breed).

Pigment formed at 37°C. Pigment especially soluble in alcohol.

Optimum temperature 30°C.

Aerobic.

Distinctive characters: It is not certain whether Breunig's original culture was a heavily pigmented strain of *Serratia marcescens*, or whether it was of the type described above. Cultures of both types have been widely distributed as the Kiel bacillus. Descriptions drawn up by Kruse (*loc. cit.*) and Lehmann and Neumann (*loc. cit.*) in 1896 state that this bacterium produces visible gas, while Migula in 1900 gives a description which fits *Serratia marcescens*. Moreover, cultures obtained under this name from various laboratories in Europe and America are sometimes of one type and sometimes of the other. As the Král culture distributed as *Bacillus ruber balticus* is widely known and has now been shown to differ from *Serratia marcescens* in that it is a distinct rod in ordinary media, forms visible gas from carbohydrates and even more abundant gas from sodium formate media, the name *Serratia kilensis* is used here for the Král culture. *Serratia kilensis* is a distinct rod like *Serratia plymuthicum*, but fails to produce acetylmethylcarbinol. This use of the name *Serratia kilensis* given here also accords with the description drawn up by Bergey for the first edition of the Manual based on the study of a culture which he obtained many years previously from Europe (Breed).

Source: From water at Kiel, Germany.

Habitat: Presumably widely distributed.

5. Serratia piscatorum (Lehmann and Neumann) Breed. (Microbe rouge de la sardine, Du Bois Saint-Sévrin, Ann. Inst. Past., *8*, 1894, 155; *Bacterium piscatorum* Lehmann and Neumann, Bakt. Diag., 1 Aufl., *2*, 1896, 263; *Bacillus ruber sardinae* Kruse, in Flügge, Die Mikroorganismen, 3 Aufl., *2*, 1896, 302; *Bacterium ruber sardinae* Chester, Ann. Rept. Del. Col. Agr. Exp. Sta., *9*, 1897, 112; *Bacillus sardinae* Migula, Syst. d. Bakt., *2*, 1900, 852; *Bacillus piscatorus* Chester, Man. Determ. Bact., 1901, 257.) From Latin *piscatorum*, of fishermen.

Short rods: 0.5 by 0.6 micron, occurring in pairs, sometimes in fours or (in broth) in long filaments. Actively motile. Gram-negative.

Gelatin colonies: Small, yellowish-gray becoming pink, very slimy. Carmine-red pellicle. Liquefaction.

Gelatin stab: Rapid liquefaction. Grayish pellicle which becomes red after 24 hours and later precipitates. Slimy.

Agar colonies: Dull, white to pinkish growth.

Broth: Rapid turbidity. Thick, slimy, white pellicle which later turns red. Purplish sediment. Liquid becomes pink and syrupy. In old cultures the broth is brown.

Potato: At 37° to 39°C, red pigment visible after 8 hours. At room temperatures growth is first white, slimy, later red.

Strong odor of trimethylamine.

Distinctive characters: Pigment soluble in alcohol, more soluble in water. Good pigment production at 37°C. Sliminess.

Source: Isolated in 1893 from a box of oil-packed sardines at a canning-factory in France. Also found in the red pus from fishermen and sardine-factory-workers suffering from felons. In these lesions, this organism is associated with an anaerobe, but by itself it is not pathogenic.

Habitat: Presumably widely distributed.

Appendix: *Serratia marcescens* has frequently been described under other names, particularly where brilliantly pigmented cultures have been found. Some of these and other related species are listed below. It is known that white

strains of these organisms occur in nature but these strains when found have probably been placed in non-chromogenic genera of the family *Enterobacteriaceae*.

Bacillus ruber Frank. (Frank, in Cohn, Beitr. z. Biol. d. Pflanz., *1*, Heft 3, 1875, 181; not *Bacillus ruber* Zimmermann, Bakt. unserer Trink- u. Nutzwässer, Chemnitz, *1*, 1890, 24; not *Bacillus ruber* Miquel, see Cent. f. Bakt., II Abt., *11*, 1903, 402; *Bacterium ruber* Chester, Ann. Rept. Del. Col. Agr. Exp. Sta., *9*, 1897, 113.) Grew in a warm place on rice cooked in chicken broth.

Bacillus subkiliensis Petrow. (Arb. bakt. Inst. Karlsruhe, *2*, Heft 3, 1902, 273.) Dust contamination from air. Reported to resemble *Bacillus kiliensis*.

Bacterium aurescens Parr. (Proc. Soc. Exp. Biol. and Med., *35*, 1937, 563). A reddish-brown organism. This and the reddish-orange organism described by Tittsler (Jour. Bact., *33*, 1937, 450), which are regarded as pigmented variants of *Escherichia coli*, resemble the organisms in *Serratia* closely but do not liquefy gelatin. From water.

Serratia amylorubra (Hefferan) Bergey et al. (*Bacillus amyloruber* Hefferan, Cent. f. Bakt., II Abt., *11*, 1903, 313; *Erythrobacillus amyloruber* Holland, Jour. Bact., *5*, 1920, 217; Bergey et al., Manual, 1st ed., 1923, 90.) From Mississippi River water and buttermilk.

Serratia esseyana Combe. (Thèse, École de Méd. Univ. Besançon, 1934, 1.) From well water at Essey. A study of an authentic culture shows this to be *Serratia marcescens* (Breed).

Serratia fuchsina (Boekhout and De Vries) Bergey et al. (*Bacillus fuchsinus* Boekhout and DeVries, Cent. f. Bakt., II Abt., *4*, 1898, 497; *Erythrobacillus fuchsinus* Holland, Jour. Bact., *5*, 1920, 218; Bergey et al., Manual, 1st ed., 1923, 91.) *Bacillus fuchsinus* Migula. (Der rote Bacillus, Lustig, Diag. d. Bakterien d. Wassers, 1893, 72; Migula, Syst. d. Bakt., *2*, 1900, 853.) Although these two organisms were named independently from different cultures, they were undoubtedly identical. The original cultures of these species appear to have been heavy pigmented strains of *Serratia marcescens* showing a metallic luster. No authentic cultures are available. From water.

Serratia gutturis Jan. (Bull. Soc. Sci. de Bretagne, *16*, 1939, 34.) From sputum. Claimed to be different from *Serratia marcescens* on the ground that it will grow on an asparagine medium and that it reduces molybdates actively.

Serratia marinorubra Zobell and Upham. (Bull. Scripps Inst. Oceanography, LaJolla, *5*, 1944, 255.) From sea water. Grew only on sea water media when first isolated but later a culture studied by Breed (1944) became adapted to growth on ordinary media and then showed the characteristics of *Serratia marcescens*.

Serratia miniacea (Zimmermann) Bergey et al. (*Bacillus miniaceus* Zimmermann, Die Bakterien unserer Trink- und Nutzwässer, Chemnitz, *1*, 1890, 46; *Erythrobacillus miniaceus* Holland, Jour. Bact., *5*, 1920, 219; Bergey et al., Manual, 1st ed., 1923, 90.) Probably a heavily pigmented strain of *Serratia marcescens* or *Serratia plymuthicum* showing metallic luster. From water.

Serratia pyoseptica (Fortineau) Bergey et al. (*Erythrobacillus pyosepticus* Fortineau, Thesis, Faculty of Medicine, Paris, 1904; abstract in Bull. Inst. Pasteur, *3*, 1905, 13; Bergey et al., Manual, 1st ed., 1923, 89.) No constant differences have been detected between *Serratia marcescens* and authentic cultures of *Serratia pyoseptica*. From the shirt of a hospital patient. Pathogenic for guinea pigs and birds. Forms a soluble toxin.

Serratia rubidaea Stapp. (*Bacterium rubidaeum* Stapp, Cent. f. Bakt., II Abt., *102*, 1940, 251; *ibid.*, 259.) From surface of plants and in composts. Characters much like those of *Serratia marcescens*.

Serratia rutilescens (Hefferan) Bergey et al. (*Bacillus rutilescens* Hefferan, Cent. f. Bakt., II Abt., *11*, 1903, 313; *Erythrobacillus rutilescens* Holland, Jour. Bact., *5*, 1920, 220; Bergey et al., Manual, 1st ed., 1923, 91.) The characters given do not distinguish this species from strains of *Serratia marcescens* that have nearly lost their power of pigment production except that it is reported to grow rapidly at 37°C. No authentic cultures appear to be available. From Mississippi River water.

Serratia rutilis (Hefferan) Bergey et al. (*Bacillus rutilis* Hefferan, Cent. f. Bakt., II Abt., *11*, 1903, 313; *Erythrobacillus rutilis* Holland, Jour. Bact., *5*, 1920, 220; Bergey et al., 1st ed., 1923, 94.) The original of this species appears to have been a heavily pigmented strain of *Serratia marcescens* or of *Serratia plymuthicum*. No characters are given that distinguish it from these species and no cultures appear to be available. From Illinois River water.

Serratia stercoraria Jan. (Bull. Soc. Sci. de Bretagne, *16*, 1939, 34.) From feces. Claimed to be different from *Serratia marcescens* because it attacks lactose, maltose and mannitol and reduces molybdates even more actively than *Serratia gutturis*.

TRIBE IV. PROTEAE CASTELLANI AND CHALMERS.

(Manual of Trop. Med., 3rd ed., 1919, 932.)

Ferments glucose but not lactose with formation of acid and usually visible gas. There is a single genus.

Genus I. **Proteus** *Hauser.**

(Hauser, Sitzber. d. phys.-med. Sozietät zu Erlangen, 1885, 156; *Liquidobacterium* Jensen, Cent. f. Bakt., II Abt., *22*, 1909, 337; *Spirilina* Hueppe, Wiesbaden, 1886, 146; *Eisenbergia* Enderlein, Sitzber. Ges. Naturf. Freunde, Berlin, 1917, 315.) From Latin, having a changeable form.

Straight rods. Gram-negative. Generally actively motile at 25°C, motility may be weak or absent at 37°C, peritrichous, occasionally very numerous flagella. Generally produce amoeboid colonies, swarming phenomenon, on moist medium. Marked pleomorphism characteristic only of very young, actively swarming cultures. Ferment glucose and usually sucrose but not lactose. Three species in fermentable carbohydrates produce small gas volumes even after prolonged incubation and an occasional culture does not produce gas. One species usually produces acid only. Urea decomposed and trimethylamine oxide reduced by all species.

The type species is *Proteus vulgaris* Hauser.

Key to the species of genus **Proteus.**

I. No action on mannitol.
  A. Acid and gas from sucrose.
    1. Acid and gas from maltose.
      a. Indole formed.
        1. *Proteus vulgaris.*
  B. Acid and gas from sucrose (delayed).
    1. No action on maltose.
      a. Indole not formed.
        2. *Proteus mirabilis.*
  C. No action on sucrose (ordinarily).
    1. No action on maltose.
      a. Indole formed.
        3. *Proteus morganii.*

II. Acid, occasionally a bubble of gas, from mannitol.
  A. Acid from sucrose (delayed).
    1. No action on maltose.
      a. Indole formed.
        4. *Proteus rettgeri.*

1. **Proteus vulgaris** Hauser. (Hauser, Sitzungsber. d. phys.-mediz. Sozietät zu Erlangen, 1885, 156; *Bacillus proteus* Trevisan, I generi e le specie delle Batteriacee, 1889, 17; *Bacterium vulgare* Lehmann and Neumann, Bakt. Diag.,

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* Originally revised by Prof. M. W. Yale, New York State Experiment Station, Geneva, New York, Nov., 1938; revised by Prof. C. A. Stuart and Dr. Robert Rustigian, Brown University, Providence, Rhode Island, May, 1943.

1 Aufl., *2*, 1896, 243; *Bacillus proteus vulgaris* Kruse, in Flügge, Die Mikroorganismen, *2*, 1896, 272; *Bacterium* (*Proteus*) *vulgaris* Chester, Ann. Rept. Del. Col. Agr. Exp. Sta., *9*, 1897, 101; *Bacillus vulgaris* Migula, Syst. d. Bakt., *2*, 1900, 707; *Bacterium proteus anindologenes* van Loghem, Ann. Inst. Past., *32*, 1918, 295; *Bacillus proteus-vulgaris* Holland, Jour. Bact., *5*, 1920, 220.) From Latin, common.

Hauser described *Proteus vulgaris* as a rapid gelatin liquefier and *Proteus mirabilis* as a slow liquefier. Wenner and Rettger (Jour. Bact., *4*, 1919, 332) found the property of liquefying gelatin too variable to serve as a basis for separation of species. They suggested that this differentiating character be set aside and the two species differentiated on the basis of maltose fermentation, the species fermenting the sugar receiving the name *Proteus vulgaris* and the species failing to attack it, *Proteus mirabilis*. This suggestion was accepted by Bergey et al., Manual, 1st ed., 1923 and Weldin, Iowa Jour. Sci., *1*, 1927, 147; and their work was confirmed by Rustigian and Stuart (Jour. Bact., *45*, 1943, 198) and by Thornton (Jour. Bact., *48*, 1944, 123). Also see Moltke (Contributions to the Characterization and Systematic Classification of *Bac. proteus vulgaris* (Hauser), Levin and Munksgaard, Copenhagen, 1927, 156).

Rods: 0.5 to 1.0 by 1.0 to 3.0 microns, occurring singly, in pairs and frequently in long chains. Actively motile, with peritrichous flagella. Gram-negative.

Gelatin colonies: Irregular, spreading, rapidly liquefying.

Gelatin stab: Rapid, stratiform liquefaction.

Agar colonies: Opaque, gray, spreading.

Agar slant: Thin, bluish-gray, spreading over entire surface.

Broth: Marked turbidity, usually with a thin pellicle.

Litmus milk: Slightly acid, becoming markedly alkaline. Quick peptonization.

Potato: Abundant, creamy to yellowish-gray growth, becoming brown.

Indole formed.

Nitrites produced from nitrates.

Acetylmethylcarbinol not formed.

Acid and gas from glucose, fructose, galactose, maltose and sucrose. No acid or gas from dextrin, lactose or mannitol. See Moltke (*loc. cit.*) for other fermentation characters. Ratio H_2 to CO_2 is 1:1 (Speck and Stark, Jour. Bact., *44*, 1942, 687).

Putrefactive odor produced.

Sodium citrate usually utilized as sole source of carbon.

Formation of H_2S: Produced from cysteine, cystine or organic sulfur compounds containing either of these molecules. Produced from sulfur and thiosulfates (Tarr, Biochem. Jour., *27*, 1933, 1869; *28*, 1934, 192). Lead acetate turned brown.

Aerobic, facultative.

Optimum temperature 37°C.

Distinctive characters: X-Strains of Weil and Felix. Lehmann-Neumann-Breed, Determinative Bact., Eng. Trans., 7th ed., *2*, 1931, 493: "The discovery of proteus strains which may be agglutinated by typhus serum is of very great importance. These are the so-called X-strains from typhus patients found by Weil and Felix. They first cultivated strains X and X_2 from the urine of typhus patients and later the famous X_{19}. The two former were agglutinated weakly, the latter strongly (up to 1:50,000). The diagnosis of typhus by agglutination with strain X_{19} proved to be excellent and the reaction took place in the serum of almost 100 per cent of those suffering from the disease. . . . The typhus strains of proteus have recently been divided into the two types of Felix and Weil, the H forms and the O forms. The former grows as a thin opaque film, the latter lacks this character and grows as non-spreading slimy colonies; frequently without dis-

tinct flagella. . . ." (For further description of H and O forms see Moltke, *loc. cit.*)

The X_2 and X_{19} strains mostly ferment maltose.

Source: From putrid meat infusions and abscesses.

Habitat: Putrefying materials.

2. **Proteus mirabilis** Hauser. (Hauser, Sitzungsber. d. phys.-mediz. Sozietät zu Erlangen, 1885, 156; *Bacillus mirabilis* Trevisan, I generi e le specie delle Batteriacee, 1889, 17; *Bacillus proteus mirabilis* Kruse, in Flügge, Die Mikroorganismen, 3 Aufl., *2*, 1896, 276; *Bacterium mirabilis* Chester, Del. Coll. Agr. Exp. Sta., 9th Ann. Rept., 1897, 101; *Bacillus pseudoramosus* Migula, Syst. d. Bakt., *2*, 1900, 817; not *Bacillus pseudoramosus* Distaso, Cent. f. Bakt., I Abt., Orig., *62*, 1912, 441; *Bacillus proteus-mirabilis* Holland, Jour. Bact., *5*, 1920, 220.) From Latin *mirabilis*, wonderful.

Short rods: 0.5 to 0.6 by 1.0 to 3.0 microns, occurring singly, in pairs and frequently in long chains. Motile, possessing peritrichous flagella. Gram-negative.

Gelatin colonies: Irregular, spreading.

Gelatin stab: Slow, stratiform liquefaction.

Agar colonies: Gray, irregular, spreading.

Agar slant: Thin, bluish-gray, spreading over surface.

Broth: Turbid, with thin gray pellicle and sediment.

Litmus milk: Slightly acid, becoming alkaline, peptonized.

Potato: Dirty-gray, spreading growth.

Indole not formed.

Acetylmethylcarbinol frequently produced weakly.

Nitrites produced from nitrates.

Acid and gas from glucose, fructose and galactose. Acid and gas usually produced slowly from sucrose. No acid or gas from lactose, maltose, dextrin or mannitol.

The XK strains are mostly maltose negative.

Putrefactive odor produced.

Hydrogen sulfide is produced.

Sodium citrate usually utilized as a sole source of carbon.

Aerobic, facultative.

Optimum temperature 37°C.

Source: From putrid meat, infusions and abscesses. Also reported as a cause of gastroenteritis (Cherry and Barnes, Amer. Jour. Pub. Health, *36*, 1946, 484).

Habitat: Putrefying materials.

3. **Proteus morganii** (Winslow et al.) Rauss. (Organism No. 1, Morgan, Brit. Med. Jour., *1*, 1906, 908; *Bacillus morgani* Winslow, Kligler and Rothberg, Jour. Bact., *4*, 1919, 481; *Bacterium morgani* Holland, Jour. Bact., *5*, 1920, 215; *Bacterium metacoli* or *Escherichia morgani* Thjøtta, Jour. Inf. Dis., *43*, 1928, 349; *Salmonella morgani* Castellani and Chalmers, Man. Trop. Med., 1919, 939; Rauss, Jour. Path. and Bact., *42*, 1936, 183; *Morganella morganii* Fulton, Jour. Bact., *46*, 1943, 81; regarded by Fulton as the type species of the genus *Morganella*.) Named for Morgan, who first isolated this organism.

Common name: Morgan's bacillus, type 1.

Rods: 0.4 to 0.6 by 1.0 to 2.0 microns, occurring singly. Motile with peritrichous flagella. See Rauss, *loc. cit.*, for discussion of flagellation and relation to the swarming characteristic. Gram-negative.

Gelatin colonies: Bluish-gray, homogeneous, smooth, entire.

Gelatin stab: No liquefaction.

Agar colonies: Grayish or bluish-white, circular, entire.

Agar slant: Grayish-white, smooth, glistening growth.

Broth: Turbid.

Litmus milk: Neutral, or becoming alkaline.

Potato: Dirty-white, limited growth.

Indole is formed.

Nitrites are produced from nitrates.

Acetylmethylcarbinol not formed.

Acid and a small amount of gas from glucose, fructose, galactose and mannose. Rarely from xylose. Does not attack lactose, sucrose, maltose, arabinose, raffinose, dextrin, salicin, mannitol, dulcitol, sorbitol, adonitol or inositol.

Hydrogen sulfide not produced.

Sodium citrate not utilized as sole source of carbon.

Aerobic, facultative.

Optimum temperature 37°C.

Source: Isolated from the feces of infants with summer diarrhea.

Habitat: In intestinal canal in normal or diarrheal stools.

4. **Proteus rettgeri** (Hadley et al.) Rustigian and Stuart. (*Bacterium rettgeri* Hadley, Elkins and Caldwell, Rhode Island Agr. Exp. Sta. Bull. 174, 1918, 169; *Bacillus rettgeri* St. John-Brooks and Rhodes, Jour. Path. and Bact., *26*, 1923, 434; *Eberthella rettgeri* Bergey et al., Manual, 1st ed., 1923, 232; *Shigella rettgeri* Weldin, Iowa State College Jour. Sci., *1*, 1927, 181; Atypical enteric organisms of the *Shigella* group, Cope and Kilander, Amer. Jour. Pub. Health, *32*, 1942, 352; *Proteus entericus* Rustigian and Stuart, Jour. Bact., *45*, 1943, 198; Rustigian and Stuart, Proc. Soc. Exp. Biol. and Med., *53*, 1943, 241.) Named for L. F. Rettger, the American bacteriologist, who isolated this species in 1904.

Rods: 0.5 to 0.8 micron long, occurring singly, in pairs and occasionally in chains. Usually non-motile at 37°C, but actively motile variants possessing peritrichous flagella can be obtained at 25°C. Gram-negative.

Gelatin colonies: Small, grayish, translucent, entire.

Gelatin stab: No liquefaction.

Agar colonies: Small, grayish, translucent, entire; under suitable conditions some strains show marked spreading.

Agar slant: Filiform to echinulate, grayish, thin, moist, translucent.

Broth: Turbid with flocculent to viscid sediment.

Litmus milk: Alkaline in eight days, becoming translucent.

Potato: Luxuriant, grayish growth.

Acid and occasionally slight gas from glucose, fructose, galactose and mannitol. Salicin may or may not be fermented. Slow and sometimes weak acid in sucrose. Lactose and maltose not fermented.

Indole is formed.

Nitrites are produced from nitrates.

Acetylmethylcarbinol not formed.

Hydrogen sulfide not produced.

Sodium citrate utilized as sole source of carbon.

Aerobic, facultative.

Optimum temperature 37°C.

Source: Originally isolated from cholera-like epidemic among chickens; recently isolated from sporadic and epidemic gastroenteritis patients.

Habitat: Fowl typhoid and some cholera-like diseases of birds.

Appendix: Acceptance of gelatin liquefaction and fermentation of glucose and sucrose but not lactose as the cardinal characteristics of *Proteus* without reference to urease production and small gas volumes has resulted in some cultures of *Paracolobactrum* (Borman et al., Jour. Bact., *48*, 1944, 361) being described as *Proteus* (Rustigian and Stuart, Jour. Bact., *49*, 1945, 419). Included in the appendix are species of *Proteus* whose taxonomic position is not clear. Where descriptions permit, the probable taxonomic position of the organism is indicated. For purposes of reference, organisms are also included which do not now merit species rank in the genus *Proteus* and organisms which will now be found in another genus.

Bacillus agglomerans Beijerinck. (Botan. Zeitung, *46*, 1888, 740 or 749.) From nodules on the roots of red clover. Colonies like those of *Proteus*.

Bacillus murisepticus pleomorphus Karlinski. (Karlinski, Cent. f. Bakt., *5*, 1889, 193; *Proteus* of Karlinski, Sternberg, Man. of Bact., 1893, 460.) From a urine discharge and from abscesses in the uterus. Sternberg regards this species as probably identical with *Proteus vulgaris* Hauser.

Flavobacterium meningitidis Hauduroy et al. (*Bacillus luteus liquefaciens* Hauduroy, Duhamel, Ehringer and Mondin, Compt. rend. Soc. Biol., Paris, *110*, 1932, 362; Hauduroy et al., Dict. d. Bact. Path., 1937, 236.) Related to this species but differing in that it ferments lactose is the following: *Bacterium coli* var. *luteoliquefaciens* Lehmann and Levy, in Lehmann and Neumann, Bakt. Diag., 4 Aufl., *2*, 1907, 314 (*Bacillus coli* var. *luteoliquefaciens* Hauduroy, Duhamel, Ehringer and Mondin, *loc. cit.*, 1932, 363).

Proteus alveicola Serbinow. (Jour. Microbiol., Petrograd, *2*, 1915, 19.) From an infectious diarrhoea of honey bees (*Apis mellifera*).

Proteus americanus Pacheco. (Sciencia Medica, *6*, 1928.) From the blood of patients with liver abscesses. Assis (Brasil Medico, No. 42-45, 1934, 35), St. John-Brooks and Rhodes (3rd Internat. Cong. for Microbiology, Rept. of Proc., 1939, 167), Rustigian and Stuart (Jour. Bact., *45*, 1943, 198) and Thornton (Jour. Bact., *48*, 1944, 123) agree that *Proteus americanus* is *Proteus mirabilis*. See Manual, 5th ed., 1939, 434 for a description of this species.

Proteus ammoniae Magath. (Magath, Jour. Inf. Dis., *43*, 1928, 181; *Salmonella ammoniae* Hager and Magath, Jour. Amer. Med. Assn., *85*, 1925, 1352.) From urine in cystitis. St. John-Brooks and Rhodes (3rd Internat. Congr. for Microbiology, Rept. of Proc., 1939, 167), Levine (Jour. Bact., *43*, 1942, 33), Rustigian and Stuart (Jour. Bact., *45*, 1943, 198) and Thornton (Jour. Bact., *48*, 1944, 123) agree that *Proteus ammoniae* is *Proteus mirabilis*. See Manual, 5th ed., 1939, 434 for a description of this species. See Fulton, Jour. Bact., *51*, 1946, 685 for the view that *Proteus ammoniae* is a valid species.

Proteus bombycis Bergey et al. (A Gram-negative bacillus, Glaser, Jour. Bact., *9*, 1924, 344; *Bacterium bombycivorum* Lehmann and Neumann, Bakt. Diag., 7 Aufl., *2*, 1927, 445; *Aerobacter bombycis* Bergey et al., Manual, 3rd ed., 1930, 334; Bergey et al., Manual, 4th ed., 1934, 365.) From diseased silk worms (*Bombyx mori*). *Proteus bombycis* appears to be a strain of *Paracolobactrum aerogenoides* Borman et al. See Manual, 5th ed., 1939, 436 for a description of this species.

Proteus diffluens (Castellani) Castellani and Chalmers. (*Bacillus diffluens* Castellani, 1915; Castellani and Chalmers, Man. Trop. Med., 3rd ed., 1919, 943.) From gastroenteritis patients. This may be a biochemical variant of *Proteus mirabilis*.

Proteus henricensis Shaw. (Sci., *65*, 1927, 477.) From putrefying materials. Said to be related to *Proteus diffluens*.

Proteus infantum (Weldin and Levine) Weldin. (Dean, Med. Jour. Australia, *1*, 1920, 27; *Bacterium infantum* Weldin and Levine, Abst. Bact., *7*, 1923, 13; Weldin, Iowa State Coll. Jour. Sci., *1*, 1926, 148.) From urine and feces of an infant.

Proteus insecticolens Steinhaus. (Jour. Bact., *42*, 1941, 763.) From the stomach of the milkweed bug (*Oncopeltus fasciatus*). This appears to be a strain of *Paracolobactrum intermedium* Borman et al.

Proteus melanovogenes Miles and Halnan. (Jour. Hyg., *37*, 1937, 79.) From eggs showing black rot. This does not appear to be a member of the genus *Proteus*.

Proteus metadiffluens (Castellani) Castellani and Chalmers. (*Bacillus metadiffluens* Castellani, 1915; Castellani and Chalmers, Manual Trop. Med., 1919, 943.) From gastroenteritis patients.

This does not appear to be a member of the genus *Proteus.*

Proteus nadsonii Lobik. (Diseases of Plants, St. Petersburg, *9*, 1915, 67.) From decomposed potatoes and tomatoes. This does not appear to be a member of the genus *Proteus.*

Proteus noctuarum (White) Bergey et al. (*Bacillus noctuarum* White, Jour. Agr. Res., *26*, 1923, 488; *Escherichia noctuarii* Bergey et al., Manual, 3rd ed., 1930, 327; Bergey et al., Manual, 4th ed., 1934, 363.) A cause of cutworm (Fam. *Noctuidae*) septicemia. Culturally identical with but serologically different from *Proteus sphingidis.*

Proteus odorans Pribram. (*Bacterium aquatile odorans* von Rigler, Hyg. Rund., *12*, 1902, 479; Pribram, Klassifikation der Schizomyceten, Leipzig and Wien, 1933, 73.) From bottled mineral waters. Aromatic odor in milk.

Proteus paraamericanus Magalhães and Aragão. (Brasil Medico, *47*, 1933, 815.) From urine. Assis (Brasil Medico, No. 42-45, 1934, 35) states that this is *Proteus mirabilis.*

Proteus paradiffluens (Castellani) Castellani and Chalmers. (*Bacillus paradiffluens* Castellani; Castellani and Chalmers, Manual Trop. Med., 3rd ed., 1919, 943.) This appears to be identical with *Proteus mirabilis.*

Proteus paramorganii Castellani and Chalmers. (Man. Trop. Med., 3rd ed., 1919, 943.) This is an H form of *Proteus morganii.*

Proteus photuris Brown. (Amer. Museum Nov., No. 251, 1927, 9.) From luminous organ of the firefly (*Photuris pennsylvanicus*). This does not appear to be a member of the genus *Proteus.*

Proteus piscicidus versicolor Babes and Riegler. (Babes and Riegler, Cent. f. Bakt., I Abt., Orig., *33*, 1902–03, 449; *Bacillus piscicidus versicolor* Nepveux, Thèse, Fac. Pharm., Paris, 1920, 114.) From diseased carp (*Cyprinus carpio*). Resembles *Proteus vulgaris.*

Proteus pseudovaleriei Assis. (Jour. Hyg., *27*, 1927, 108.) Rustigian and Stuart (Proc. Soc. Exper. Biol. and Med., *53*, 1943, 241) state that this is a paracolon organism, presumably *Paracolobactrum coliforme* Borman et al. See Manual, 5th ed., 1939, 435 for a description of this species.

Proteus recticolens Steinhaus. (Jour. Bact., *42*, 1941, 763.) From pylorus and rectum of the milkweed bug (*Oncopeltus fasciatus*). This appears to be a strain of *Paracolobactrum intermedium* Borman et al.

Proteus sphingidis (White) Bergey et al. (*Bacillus sphingidis* White, Jour. Agr. Res., *26*, 1923, 49; *Escherichia sphingidis* Bergey et al., Manual, 3rd ed., 1930, 327; Bergey et al., Manual, 4th ed., 1934, 366.) A cause of hornworm septicemia (*Protoparce sexta* Johan. and *P. quinquemaculata* Haw.). See Manual, 5th ed., 1939, 605 for a description of this species. White (*loc. cit.*) regards this species as possibly identical with *Coccobacillus acridiorum* d'Herelle.

Proteus sulfureus Holschewnikoff. (Holschewnikoff, Fortschr. d. Med., *7*, 1889, 201 and Ann. de Microgr., *1*, 1888–1889, 257; *Bacillus lindenborni* Trevisan, I generi e le specie delle Batteriacee, 1889, 17; *Bacillus sulfureus* Migula, Syst. d. Bakt., *2*, 1900, 698; not *Bacillus sulfureus* Trevisan, I generi e le specie delle Batteriacee, 1889, 17.) From water. Similar to or perhaps identical with *Proteus vulgaris* Hauser. Produces H_2S.

Proteus sp. Steinhaus. (Jour. Bact., *42*, 1941, 764.) This organism appears to be a strain of *Paracolobactrum intermedium* Borman et al.

Proteus sp. Warren and Lamb. (Jour. Med. Res., *44*, 1924, 375.) From feces and blood of patient with a fatal infection. This organism does not appear to be a member of the genus *Proteus.*

Urobacillus liquefaciens septicus Krogius. (Compt. rend. Soc. Biol., Paris, *2*, 1890, 65.) Regarded by Lehmann and Neumann (Bakt. Diag., 1 Aufl., *2*, 1896, 243) as a synonym of *Proteus vulgaris.*

TRIBE V. SALMONELLEAE BERGEY, BREED AND MURRAY.

(Preprint, Manual, 5th ed., October, 1938, vi.)

Rods that are either motile with peritrichous flagella or non-motile. Attack numerous carbohydrates with the formation of acid, or acid and gas. Lactose, sucrose and salicin are not ordinarily attacked. Do not produce acetylmethylcarbinol. Gelatin not liquefied (exceptions have been noted, but are rare). Urea not hydrolyzed. Milk not peptonized. No spreading growth on ordinary 2 to 3 per cent agar. Live in the bodies of warm-blooded animals, including man, occasionally in reptiles, and frequently in food eaten by these animals.

Key to the genera of tribe Salmonelleae.

I. Ferments glucose with the formation of acid and, with few exceptions, gas.
Genus I. *Salmonella*, p. 492.

II. Ferments glucose with the formation of acid but, with rare exceptions, no gas.
Genus II. *Shigella*, p. 535.

Genus I. Salmonella *Lignières.**

(Rec. de méd. vét., Sér. 8, 7, 1900, 389.)

Usually motile, but non-motile forms occur. Produce acid and gas from glucose, maltose, mannitol and sorbitol (except that in *Salmonella typhosa* and *S. gallinarum* no gas is produced). Lactose, sucrose and salicin not attacked. Do not clot milk, form indole or liquefy gelatin. Reduce trimethylamine oxide to trimethylamine.† All of the known species are pathogenic for warm-blooded animals, including man, causing food infections and enteric fevers. A few are found in reptiles. Some or all may also live in decomposing foods.

Although fermentation of lactose, sucrose and salicin, formation of indole, gelatin liquefaction and failure to produce gas have been described for organisms serologically belonging to *Salmonella*, the practical recognition of this genus and studies of its constituent species suggest that these be looked upon as exceptions which do not invalidate the biochemical definition of the genus. Serological definition of the limits of the genus is fraught with many practical and theoretical difficulties. Indeed, there is increasing evidence of antigenic affinities of varying degree between *Escherichia*, *Salmonella* and *Shigella*. This is well reviewed by Bornstein (Jour. Immunol., *46*, 1943, 439). Within the limits of the genus *Salmonella*, serological rela-

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* Completely revised by Prof. Frederick Smith, McGill Univ., Montreal, P. Q., Canada, December, 1938; further revision, 1946. Manuscript read by Dr. F. Kauffmann, State Serum Institute, Copenhagen, Denmark and by Dr. Philip Edwards and Dr. D. W. Bruner, Agri. Exper. Sta., Lexington, Kentucky, May, 1946. These specialists have also assisted in completing references and in compiling records of the distribution of types.

† Wood and Baird, Jour. Fish. Res. Board Canada, *6*, 1943, 194.

tionships are the chief means of identifying new strains. There is general dissatisfaction with the granting of species rank to each one of the rapidly mounting number of types. The purposes of the greater number of bacteriologists, however, will be best served for the present by listing the known types.

There is a wide difference between the viewpoint of those who think of the serological types recognized in this genus as species, e.g., Schütze et al. (Jour. Hyg., *34*, 1934, 333) and the more recently expressed viewpoint of Borman, Stuart and Wheeler (Jour. Bact., *48*, 1944, 351). The latter authors recognize only three species in the genus, *Salmonella choleraesuis*, *S. typhosa* and *S. kauffmannii*. In the second report by Schütze et al. (Proc. 3rd Internat. Cong. Microbiol., New York, 1940, 832) the so-called species listed in the first report by this Sub-committee are designated as types.

Kauffmann, who recognizes nearly 150 serotypes in the group, nevertheless notes in a recent paper (Acta Path. et Microbiol. Scand., *22*, 1945, 144) that five types are of special interest in the field of human medicine, *Salmonella paratyphi A*, *Salmonella paratyphi B*, *Salmonella paratyphi C*, *Salmonella typhi* and *Salmonella sendai;* and that six types are of special interest in the field of veterinary medicine, *Salmonella typhimurium*, *Salmonella abortusequi*, *Salmonella abortusovis*, *Salmonella choleraesuis*, *Salmonella enteritidis* and *Salmonella gallinarum-pullorum*.

The 150 or more serotypes are, in a way, comparable to the 50 or more serotypes of *Diplococcus pneumoniae* that are recognized on the basis of agglutination with immune serums. The serological methods used have proved to be of fundamental value as they provide useful diagnostic procedures by means of which unknown cultures can be accurately and quickly identified.

As the morphology, staining properties and physiology of the bacteria belonging to the various types are practically identical, only the antigenic structure, source and habitat (so far as the latter is known) have been recorded for the majority of the types listed. Even though there is much duplication, descriptions similar to those used elsewhere in the MANUAL are given for the eleven types that are of greatest interest. Special mention has also been made of unusual characters such as failure to produce gas from glucose, lactose fermentation, indole production and gelatin liquefaction.

The nomenclature used for this group presents a special problem. It developed from labelings used for cultures. These were designated by the name of a patient, e.g., Thompson; by the name of the hospital where the patient was placed, e.g., Virchow, Bispebjerg; or more frequently by the name of the village, locality or city where the outbreak occurred or was studied, e.g., Borbeck, Altendorf, Tel Aviv. The names of states and larger areas have also been used, e.g., Kentucky, Italia, etc. Recently several types have been named in honor of well-known bacteriologists, e.g., Berta, Gaminara, Arechavaleta. As this useful laboratory labeling is not in the form ordinarily used by taxonomists, various suggestions have been made regarding the development of a binomial nomenclature comparable to that more generally used. None of these suggestions has been generally accepted as yet. For example, Haupt (Ergebnisse d. Hyg., *13*, 1932, 673) and others who have thought of the serotypes as species have added Latin endings to the place and other proper names that have been used, e.g., *Salmonella readingensis*, *S. rostockensis*. Schütze et al. (Jour. Hyg., *34*, 1934, 333) accepted the view that the place and other names should be used in binomials without adding Latin endings. Kauffmann (Ztschr. f. Hyg., *120*, 1938, 193), on the other hand, has suggested that letters and numbers, e.g., *Salmonella* B2, or even (Acta Path. et Microbiol. Scand., *22*, 1945, 147) the antigenic formula be used with the generic name, e.g., *Salmonella* IV, V, XII . . . b ↔ 1, 2 . . . instead of *Salmonella paratyphi B*.

The nomenclature used in the present edition of the MANUAL is slightly modified from that used in the fifth edition. The form adopted is in accordance with the view that the recognition of similar antigenic structures really identifies serotypes rather than species. In a way, serotypes are varieties in a taxonomic sense, though like horticultural varieties in higher plants, they do not exactly correspond with varieties as usually defined by taxonomists. Where cultural differences rather than antigenic structure have been used to subdivide species, these subdivisions are designated as varieties.

As it is not clear as yet how many and what species will eventually be recognized, the form *Salmonella sp.* has been used as before to indicate that the serotypes belong to species in the genus *Salmonella* which are not yet definitely defined. Geographic and other proper names are used to designate types as these have been used extensively in the literature. They have an historic significance and are not as easily confused as are letters and numbers. No Latin endings have been used for these place names as this might indicate that the serotype names are accepted as species names.

The genus *Eberthella* has been combined with the genus *Salmonella* as recommended by Schütze et al. (*loc. cit.*). With the exception of the typhoid organism, other species previously listed in *Eberthella* appear not to exist in type culture collections. As cultures are not available for study, these species are merely listed in an appendix to the genus *Salmonella*.

The type species is *Salmonella choleraesuis* (Smith) Weldin.

The table on pages 495 to 500 is used in place of the usual key.

Serological Types in the Genus **Salmonella**—*Antigenic Structure.*

Group	No.	Types	Somatic (O) Antigens	Flagellar (H) Antigens Phase 1	Flagellar (H) Antigens Phase 2
A	1	*Salmonella paratyphi*	[I], II, XII	a	—
B	2	*Salmonella schottmuelleri*	[I], IV, [V], XII	b	[1, 2]
	3	*Salmonella sp.* (Type Abony)	[I], IV, V, XII	b	e, n, x
	4	*Salmonella typhimurium*	[I], IV, [V], XII	i	1, 2, 3
	5	*Salmonella sp.* (Type Köln)	IV, V, XII	y	1, 2, 3
	6	*Salmonella sp.* (Type Stanley)	IV, V, XII	d	1, 2
	7	*Salmonella sp.* (Type Heidelberg)	IV, V, XII	r	1, 2, 3
	8	*Salmonella sp.* (Type Chester)	IV, [V], XII	e, h	e, n, x
	9	*Salmonella sp.* (Type San Diego)	IV, [V], XII	e, h	e, n, z_{15}
	10	*Salmonella sp.* (Type Salinas)	IV, XII	d, e, h	d, e, n, z_{15}
	11	*Salmonella sp.* (Type Saint Paul)	I, IV, V, XII	e, h	1, 2, 3
	11a	(*Salmonella sp.* (Type Zagreb))	IV, V, XII	e, h	1, 2
	12	*Salmonella sp.* (Type Reading)	IV, XII	e, h	1, 5
	12a	(*Salmonella sp.* (Type Kaposvar))	IV, V, XII	e, (h)	1, 5
	13	*Salmonella sp.* (Type Kaapstad)	IV, XII	e, h	1, 7
	14	*Salmonella sp.* (Type Derby)	[I], IV, XII	f, g	—
	15	*Salmonella sp.* (Type Essen)	IV, XII	g, m	—
	16	*Salmonella sp.* (Type Budapest)	I, IV, XII	g, t	—
	17	*Salmonella sp.* (Type California)	IV, XII	g, m, t	—
	18	*Salmonella sp.* (Type Brandenburg)	IV, XII	l, v	e, n, z_{15}
	19	*Salmonella sp.* (Type Bispebjerg)	I, IV, XII	a	e, n, x
	20	*Salmonella abortivoequina*	IV, XII	—	e, n, x
	21	*Salmonella sp.* (Type Arechavaleta)	IV, [V], XII	a	1, 7
	22	*Salmonella abortusovis*	IV, XII	c	1, 6
	23	*Salmonella sp.* (Type Altendorf)	IV, XII	c	1, 7
	24	*Salmonella sp.* (Type Texas)	IV, V, XII	k	e, n, z_{15}

[ ] signifies that this antigen may be absent. ( ) signifies that only a part of this antigen is present.

Serological Types in the Genus **Sa'monella**—*Antigenic Structure—Continued.*

Group	No.	Types	Somatic (O) Antigens	Flagellar (H) Antigens	
				Phase 1	Phase 2
B	25	*Salmonella abortusbovis*	[I], IV, XXVII, XII	b	e, n, x
	26	*Salmonella sp.* (Type Bredeney)	I, IV, [XXVII], XII	l, v	1, 7
	27	*Salmonella sp.* (Type Schleissheim)	IV, XXVII, XII	b, z_{12}	—
	28	*Salmonella sp.* (Type Schwarzengrund)	·I, IV, XXVII, XII	d	1, 7
C_1	29	*Salmonella hirschfeldii*	VI, VII, [Vi]	c	1, 5
	30	*Salmonella choleraesuis*	VI, VII	[c]	1, 5
	31	*Salmonella typhisuis*	VI, VII	[c]	1, 5
	32	*Salmonella sp.* (Type Thompson)	VI, VII	[k]	1, 5
	33	*Salmonella sp.* (Type Montevideo)	VI, VII	g, m, s	—
	34	*Salmonella sp.* (Type Oranienburg)	VI, VII	m, t	—
	35	*Salmonella sp.* (Type Virchow)	VI, VII	r	1, 2, 3
	36	*Salmonella sp.* (Type Oslo)	VI, VII	a	e, n, x
	37	*Salmonella sp.* (Type Amersfoort)	VI, VII	d	e, n, x
	38	*Salmonella sp.* (Type Braenderup)	VI, VII	e, h	e, n, z_{15}
	39	*Salmonella sp.* (Type Potsdam)	VI, VII	l, v	e, n, z_{15}
	40	*Salmonella sp.* (Type Bareilly)	VI, VII	y	1, 5
	41	*Salmonella sp.* (Type Hartford)	VI, VII	y	e, n, x
	42	*Salmonella sp.* (Type Mikawasima)	VI, VII	y	e, n, z_{15}
	43	*Salmonella sp.* (Type Tennessee)	VI, VII	z_{29}	—
	44	*Salmonella sp.* (Type Concord)	VI, VII	l, v	1, 2, 3
	45	*Salmonella sp.* (Type Infantis)	VI, VII	r	1, 5
	46	*Salmonella sp.* (Type Georgia)	VI, VII	b	e, n, z_{15}
	47	*Salmonella sp.* (Type Papua)	VI, VII	r	e, n, z_{15}
	48	*Salmonella sp.* (Type Richmond)	VI, VII	y	1, 2, 3
	49	*Salmonella sp.* (Type Cardiff)	VI, VII	k	1, 10
	50	*Salmonella sp.* (Type Daytona)	VI, VII	k	1, 6

	51	*Salmonella sp.* (Type Newport)	VI, VIII	[e, h]	1, 2, 3
	52	*Salmonella sp.* (Type Pueris)	VI, VIII	e, h	1, 2
	53	*Salmonella sp.* (Type Kottbus)	VI, VIII	e, h	1, 5
	54	*Salmonella sp.* (Type Muenchen)	VI, VIII	d	1, 2
C_2	54a	(*Salmonella sp.* (Type Oregon))	VI, VIII	d	1, 2, 3
	55	*Salmonella sp.* (Type Manhattan)	VI, VIII	d	1, 5
	56	*Salmonella sp.* (Type Litchfield)	VI, VIII	l, v	1, 2, 3
	57	*Salmonella morbificans*	VI, VIII	r	1, 5
	58	*Salmonella sp.* (Type Narashino)	VI, VIII	a	e, n, x
	59	*Salmonella sp.* (Type Buenos Aires)	VI, VIII	i	e, n, x
	60	*Salmonella sp.* (Type Glostrup)	VI, VIII	z_{10}	e, n, z_{15}
	61	*Salmonella sp.* (Type Duesseldorf)	VI, VIII	z_4, z_{24}	—
	62	*Salmonella sp.* (Type Tallahassee)	VI, VIII	z_4, z_{32}	—
	63	*Salmonella sp.* (Type Gatun)	VI, VIII	b	e, n, x
	64	*Salmonella sp.* (Type Amherst)	(VIII)	l, v	1, 6
	65	*Salmonella sp.* (Type Virginia)	(VIII)	d	—
	66	*Salmonella typhosa*	IX, XII, [Vi],	d	—
	67	*Salmonella enteritidis*	[I], IX, XII	g, m	—
	68	*Salmonella sp.* (Type Dublin)	I, IX, XII	g, p	—
D	69	*Salmonella sp.* (Type Rostock)	I, IX, XII	g, p, u	—
	70	*Salmonella sp.* (Type Moscow)	IX, XII	g, q	—
	71	*Salmonella sp.* (Type Blegdam)	IX, XII	g, m, q	—
	72	*Salmonella sp.* (Type Berta)	IX, XII	f, g, t	—
	73	*Salmonella sp.* (Type Pensacola)	IX, XII	g, m, t	—
	74	*Salmonella sp.* (Type Claiborne)	I, IX, XII	k	1, 5
	75	*Salmonella sp.* (Type Sendai)	[I], IX, XII	a	1, 5
	76	*Salmonella sp.* (Type Miami)	IX, XII	a	1, 5
	77	*Salmonella sp.* (Type Durban)	IX, XII	a	e, n, z_{15}
	78	*Salmonella sp.* (Type Onarimon)	I, IX, XII	b	1, 2

[ ] signifies that this antigen may be absent. ( ) signifies that only a part of this antigen is present.

Serological Types in the Genus **Salmonella**—*Antigenic Structure—Continued.*

Group	No.	Types	Somatic (O) Antigens	Flagellar (H) Antigens	
				Phase 1	Phase 2
D	79	*Salmonella sp.* (Type Eastbourne)	[I], IX, XII	e, h	1, 5
	80	*Salmonella sp.* (Type Panama)	I, IX, XII	l, v	1, 5
	81	*Salmonella sp.* (Type Dar-es-Salaam)	I, IX, XII	l, w	e, n
	82	*Salmonella sp.* (Type Goettingen)	IX, XII	l, v	e, n, z_{15}
	83	*Salmonella sp.* (Type Java)	[I], IX, XII	l, z_{25}	1, 5
	84	*Salmonella gallinarum*	[I], IX, XII	—	—
	85	*Salmonella pullorum*	IX, XII	—	—
	86	*Salmonella sp.* (Type Canastel)	IX, XII	z_{29}	1, 5
	87	*Salmonella sp.* (Type Italia)	IX, XII	l, v	1, 11
	88	*Salmonella sp.* (Type Napoli)	[I], IX, XII	l, z_{13}	e, n, x
	89	*Salmonella sp.* (Type Loma Linda)	IX, XII	a	e, n, x
	90	*Salmonella sp.* (Type New York)	IX, XII	l, v	1, 5
E_1	91	*Salmonella sp.* (Type London)	III, X, XXVI	l, v	1, 6
	92	*Salmonella sp.* (Type Give)	III, X, XXVI	l, v	1, 7
	93	*Salmonella sp.* (Type Uganda)	III, X, XXVI	l, z_{13}	1, 5
	94	*Salmonella anatis*	III, X, XXVI	e, h	1, 6
	95	*Salmonella sp.* (Type Muenster)	III, X, XXVI	e, h	1, 5
	96	*Salmonella sp.* (Type Nyborg)	III, X, XXVI	e, h	1, 7
	97	*Salmonella sp.* (Type Vejle)	III, X, XXVI	e, h	1, 2, 3
	98	*Salmonella sp.* (Type Meleagris)	III, X, XXVI	e, h	l, w
	99	*Salmonella sp.* (Type Shangani)	III, X, XXVI	d	1, 5
	100	*Salmonella sp.* (Type Zanzibar)	III, X, XXVI	k	1, 5
	101	*Salmonella sp.* (Type Amager)	III, X, XXVI	y	1, 2, 3
	102	*Salmonella sp.* (Type Lexington)	III, X, XXVI	z_{10}	1, 5
	103	*Salmonella sp.* (Type Weltevreden)	III, X, XXVI	r	z_6

E_2	104	*Salmonella sp.* (Type Orion)	III, X, XXVI	y	1, 5
	105	*Salmonella sp.* (Type Butantan)	III, X, XXVI	b	1, 5
	106	*Salmonella sp.* (Type Newington)	III, XV	e, h	1, 6
	107	*Salmonella sp.* (Type Selandia)	III, XV	e, h	1, 7
	108	*Salmonella sp.* (Type New Brunswick)	III, XV	l, v	1, 7
	109	*Salmonella sp.* (Type Illinois)	(III), (XV), XXXIV	z_{10}	1, 5
E_3	110	*Salmonella sp.* (Type Senftenberg)	I, III, XIX	g, s, t	—
	111	*Salmonella sp.* (Type Niloese)	I, III, XIX	d	z_6
	112	*Salmonella sp.* (Type Simsbury)	I, III, XIX	z_{27}	—
	113	*Salmonella sp.* (Type Taksony)	I, III, XIX	i	z_6
F	114	*Salmonella sp.* (Type Kentucky)	(VIII), XX	i	z_6
	115	*Salmonella sp.* (Type Aberdeen)	XI	i	1, 2, 3
	116	*Salmonella sp.* (Type Rubislaw)	XI	r	e, n, x
	117	*Salmonella sp.* (Type Pretoria)	XI	k	1, 2, 3
	118	*Salmonella sp.* (Type Venezia)	XI	i	e, n, x
	119	*Salmonella sp.* (Type Solt)	XI	y	1, 5
	120	*Salmonella sp.* (Type St. Lucie)	XI	a	e, n, z_{15}
	121	*Salmonella sp.* (Type Senegal)	XI	r	1, 5
	122	*Salmonella sp.* (Type Marseille)	XI	a	1, 5
	123	*Salmonella sp.* (Type Grumpy)	XIII, XXII,	d	1, 7
	124	*Salmonella sp.* (Type Poona)	XIII, XXII	z	1, 6
	125	*Salmonella sp.* (Type Borbeck)	XIII, XXII	l, v	1, 6
	126	*Salmonella sp.* (Type Mississippi)	I, XIII, XXIII	b	1, 5
	127	*Salmonella sp.* (Type Wichita)	I, XIII, XXIII	d	—
	128	*Salmonella sp.* (Type Havana)	I, XIII, XXIII	f, g	—
	129	*Salmonella sp.* (Type Worthington)	I, XIII, XXIII	l, w	z
	130	*Salmonella sp.* (Type Cuba)	I, XIII, XXIII	z_{29}	—
	131	*Salmonella sp.* (Type Heves)	VI, XIV, XXIV	d	1, 5

[ ] signifies that this antigen may be absent. ( ) signifies that only a part of this antigen is present.

Serological Types in the Genus **Salmonella**—*Antigentic Structure—Concluded.*

Group	No.	Types	Somatic (O) Anntigens	Flagellar (H) Antigens	
				Phase 1	Phase 2
	132	*Salmonella sp.* (Type Carrau)	VI, XIV, XXIV	y	1, 7
	133	*Salmonella sp.* (Type Onderstepoort)	(I), VI, XIV, XXV	e, (h)	1, 5
	134	*Salmonella sp.* (Type Florida)	(I), VI, XIV, XXV	d	1, 7
	135	*Salmonella sp.* (Type Madelia)	(I), VI, XIV, XXV	y	1, 7
	136	*Salmonella sp.* (Type Sundsvall)	(I), VI, XIV, XXV	z	e, n, x
	137	*Salmonella sp.* (Type Orient)	XVI	k	e, n, z_{16}
	138	*Salmonella sp.* (Type Hvittingfoss)	XVI	b	e, n, x
	139	*Salmonella sp.* (Type Gaminara)	XVI	d	1, 7
F	140	*Salmonella sp.* (Type Szentes)	XVI	k	1, 2, 3
	141	*Salmonella sp.* (Type Kirkee)	XVII	b	1, 2
	142	*Salmonella sp.* (Type Cerro)	XVIII	z_4, z_{23}, z_{25}	—
	143	*Salmonella sp.* (Type Minnesota)	XXI, XXVI	b	e, n, x
	144	*Salmonella sp.* (Type Tel Aviv)	XXVIII	y	e, n, z_{15}
	145	*Salmonella sp.* (Type Pomona)	XXVIII	y	1, 7
	146	*Salmonella sp.* (Type Ballerup)	XXIX, [Vi]	z_{14}	—
	147	*Salmonella sp.* (Type Hormaeche)	XXIX, [Vi]	z_{30}, [z_{31}]	—
	148	*Salmonella sp.* (Type Urbana)	XXX	b	e, n, x
	149	*Salmonella sp.* (Type Adelaide)	XXXV	f, g	—
	150	*Salmonella sp.* (Type Inverness)	XXXVIII	k	1, 6
	151	*Salmonella sp.* (Type Champaign)	XXXIX	k	1, 5

[ ] signifies that this antigen may be absent. ( ) signifies that only a part of this antigen is present.

1. **Salmonella paratyphi** (Kayser) Castellani and Chalmers. (*Bacterium paratyphi* Typus A, Brion and Kayser, Münch. med. Wchnschr., *49*, 1902, 611; *Bacterium paratyphi* Kayser, Cent. f. Bakt., I Abt., Orig., *31*, 1902, 426; *Bacillus paratyphosus A* Boycott, Jour. Hyg., *6*, 1906, 33; *Bacillus paratyphi* Winslow and Kligler, Jour. Bact., *1*, 1916, 81; *Bacillus paratyphosus* Winslow, Kligler and Rothberg, Jour. Bact., *4*, 1919, 474; *Salmonella paratyphi* and *Salmonella paratyphi A* Castellani and Chalmers, Man. Trop. Med., 3rd ed., 1919, 938 and 939; *Bacterium paratyphosum A* Holland, Jour. Bact., *5*, 1920, 219.) From Latin *para*, like and *typhus*, typhoid.

Rods: 0.6 by 3.0 to 4.0 microns, occurring singly. Motile with peritrichous flagella. Gram-negative.

Gelatin colonies: Bluish-gray, homogeneous, smooth, glistening, entire to slightly undulate.

Gelatin stab: Fair surface growth. No liquefaction.

Agar colonies: Grayish, homogeneous, smooth, glistening, entire to slightly undulate.

Agar slant: Filiform, grayish, smooth, glistening growth.

Broth: Turbid, with slight grayish sediment.

Litmus milk: Slightly acid.

Potato: Limited, dirty-white streak.

Indole not formed.

Nitrites produced from nitrates.

Acid and gas from glucose, fructose, galactose, mannose, arabinose, maltose, trehalose, dextrin, glycerol, mannitol, dulcitol, rhamnose and sorbitol. No acid or gas from lactose, sucrose, raffinose, xylose, salicin, inulin, adonitol or inositol.

Reduces trimethylamine oxide (Wood and Baird, Jour. Fish. Res. Bd. Canada, *6*, 1943, 198).

No hydrogen sulfide formed.

Aerobic, facultative.

Optimum temperature 37°C.

Antigenic structure: [I], II, XII: a:—. (Type Durazzo lacks I).

Source: Isolated from enteric fever in man. Not known to be a natural pathogen of animals.

Habitat: A natural pathogen of man causing enteric fever.

2. **Salmonella schottmuelleri** (Winslow et al.) Bergey et al. (Bacilli paratyphique, Achard and Bensaude, Soc. Méd. des Hôp. de Paris, *13*, 1896, 679; *Bacillus paratyphi alcaligenes* Schottmüller, Deutsche med. Wchnschr., *32*, 1900, 511; *Bacterium paratyphi* Typus B, Brion and Kayser, Münch. med. Wchnschr., *49*, 1902, 611; *Bacillus paratyphosus B* Boycott, Jour. Hyg., *6*, 1906, 33; *Bacterium paratyphosum B* Le Blaye and Guggenheim, Manuel Pratique de Diag. Bact., 1914; *Bacillus schottmülleri* Winslow, Kligler and Rothberg, Jour. Bact., *4*, 1919, 479; *Salmonella paratyphi B* Castellani and Chalmers, Man. Trop. Med., 3rd ed., 1919, 939; *Bacterium schottmülleri* Holland, Jour. Bact., *5*, 1920, 222; included in Group IV of Hecht-Johansen, Copenhagen, 1923; Bergey et al., Manual, 1st ed., 1923, 213.) Named for Prof. Schottmüller who isolated this organism in 1899.

Rods: 0.6 to 0.7 by 2.0 to 3.0 microns, occurring singly and in pairs. Motile with peritrichous flagella. Gram-negative.

Gelatin stab: No liquefaction.

Agar colonies: Small, circular, bluish-gray, transparent, homogeneous, entire to undulate.

Broth: Turbid with thin gray pellicle and sediment. Fecal odor.

Litmus milk: Slightly acid, becoming alkaline.

Potato: Grayish-white, viscous growth.

Indole not formed.

Nitrites produced from nitrates.

Acid and gas from glucose, fructose, galactose, mannose, arabinose, xylose, maltose, dextrin, trehalose, glycerol,

mannitol, dulcitol, sorbitol, rhamnose and inositol. No acid or gas from lactose, sucrose, inulin, salicin or adonitol and usually not from raffinose.

Reduces trimethylamine oxide (Wood and Baird, *loc. cit.*).

Hydrogen sulfide produced.

Optimum temperature 37°C.

Aerobic, facultative.

Antigenic structure: [I], IV, [V], XII: b: [1,2]. . . . Some strains lack antigen V and some have I.

Source: Isolated from cases of enteric fever in man. Not a natural pathogen of animals.

Habitat: A natural pathogen of man causing enteric fever. Also found rarely in cattle, sheep, swine, lower primates and chickens.

3. **Salmonella sp.** (Type Abony). (*Salmonella abony* Kauffmann, Acta Path. et Microbiol. Scand., *17*, 1940, 1.)

Antigenic structure: [I], IV, V, XII: b: e, n, x. . . .

Source: Isolated by Kauffmann from a mixed culture of *Salmonella abortus bovis* sent to him by Dr. K. Rauss, Budapest. Later three additional cultures were received from Dr. Rauss. Original culture from the feces of a normal person.

Habitat: All cultures thus far recognized have been from human sources.

4. **Salmonella typhimurium** (Loeffler) Castellani and Chalmers. (*Bacillus typhi murium* Loeffler, Cent. f. Bakt., *11*, 1892, 192; *Bacterium typhi murium* Chester, Ann. Rept. Del. Col. Agr. Exp. Sta., *9*, 1897, 70; *Bacillus murium* Migula, Syst. d. Bakt., *2*, 1900, 761; Castellani and Chalmers, Man. Trop. Med., 3rd ed., 1919, 939; *Bacillus typhi-murium* Holland, Jour. Bact., *5*, 1920, 221; *Bacterium typhi-murium* Holland, *idem*; *Bacillus enteritidis B, Typ. murium* Januschke, Ztschr. f. Infektionskr. d. Haustiere, *27*, 1924, 182.)

The following are regarded as synonyms of this organism: *Salmonella psittacosis* Castellani and Chalmers (Man. Trop. Med., 3rd ed., 1919, 939; *Bacillus psittacosis* Nocard, Conseil d. Hyg. Publique et Salubrité du Dept. du Seine, Séance, March 24, 1893; *Bacterium psittacosis* Le Blaye and Guggenheim, Manuel Pratique de Diagnostic Bactériologique, 1914); *Salmonella aertrycke* Castellani and Chalmers (Man. Trop. Med., 3rd ed., 1919, 939; *Bacillus aertrycke* De Nobele, Ann. Soc. Méd. Gand., *72*, 1898, 281; *Bacillus para-aertrycke* Castellani, Ann. di Med. Nav. e Colon., *11*, 1914, 453; *Bacterium aertrycke* Weldin and Levine, Abst. Bact., *7*, 1923, 13); Kaensche's *Bacillus* and Basenau's *Bacillus*, Kaensche, Ztschr. f. Hyg., *22*, 1896, 53; *Bacillus pestis-caviae* Wherry (Jour. Inf. Dis., *5*, 1908, 519; *Bacillus cholera-caviae* Wherry, Pub. Health Repts., November, 1908; *Pasturella pestis-caviae* Holland, Jour. Bact., *5*, 1920, 219); *Bacillus paratyphosus B*, Mutton type, Schütze, Lancet, *1*, 1920, 93; Group VII of Hecht-Johansen, Copenhagen, 1923; *Salmonella aertrycke* Ibrahim and Schütze, Brit. Jour. Exp. Path., *9*, 1928, 353; *Bacterium enteritidis Breslau* and *Salmonella breslau* of German literature; Mouse-typhoid of many authors. Some strains are confused with *Salmonella anatis* because of their origin in ducklings, e.g., see *Salmonella anatum* var. *aertrycke* Olsen and Goetchins, Cornell Vet., *27*, 1937, 354.

Hauduroy et al. (Dict. d. Bact. Path., Paris, 1937, 449) regard the following as synonyms of *Salmonella aertrycke: Bacillus breslaviensis* Kruse, in Flügge, Die Mikroorganismen, 3 Aufl., *2*, 1896, 377; *Bacterium breslaviensis* Chester, Ann. Rept. Del. Col. Agr. Exp. Sta., *9*, 1897, 69; *B. enteritidis breslaviense* Berge, Deut. tierärztl. Wchnschr., 1926, 473; *Salmonella meleagridis* Rettger, Plastridge and Cameron, Jour. Inf. Dis., *53*, 1933, 279; *Salmonella aertrycke* var. *meleagridis* Cameron and Rettger, Jour. Bact., *27*, 1934, 86.

See Edwards and Bruner, Kentucky

Agr. Exp. Sta. Bull. 400, 1940, 43-70, for a discussion of this species.

Rods: 0.5 by 1.0 to 1.5 microns, occurring singly. Motile with peritrichous flagella. Gram-negative.

Gelatin colonies: Small, circular, grayish, granular, becoming yellowish-brown.

Gelatin stab: Flat surface growth. No liquefaction.

Agar colonies: Small, circular, grayish, entire to undulate.

Agar slant: Filiform, grayish, moist, entire growth.

Broth: Turbid.

Litmus milk: Slightly acid, becoming alkaline.

Potato: Grayish-white streak.

Indole not formed.

Nitrites produced from nitrates.

Acid and gas from glucose, fructose, galactose, arabinose, maltose, dextrin, mannitol, sorbitol and inositol. Acid from glycerol. No action on lactose, sucrose, raffinose, inulin, salicin or adonitol.

Reduces trimethylamine oxide (Wood and Baird, *loc. cit.*).

Hydrogen sulfide produced.

Optimum temperature 37°C.

Aerobic, facultative.

Antigenic structure: [I], IV, [V], XII: i: 1, 2, 3 . . .

Source: Isolated during a mouse typhoid epidemic in the Hygienic Institute of Greifswald, Germany.

Habitat: Causes food-poisoning in man. A natural pathogen for all warm-blooded animals. This type occurs more frequently than any other type not confined to a specific host. Also found in snakes by Hinshaw and McNeil (Amer. Jour. Vet. Res., *6*, 1945, 264).

4a. *Salmonella typhimurium* (Type Binns). (*Bacillus paratyphosus B* Binns type, Schütze, Lancet, *1*, 1920, 93; Group VI of Hecht-Johansen, Copenhagen, 1923; Typus-Binns, Kauffmann, Zbl. f. d. ges. Hyg., *25*, 1931, 273; *Salmonella typhimurium* var. *Copenhagen*, Kauffmann, Ztschr. f. Hyg., *116*, 1934, 368; *Salmonella typhi-murium* var. *Binns*, Schütze et al., Jour. Hyg., *34*, 1934, 339; *Salmonella aertrycke* var. *Storrs*, Edwards, Jour. Bact., *30*, 1935, 471.)

Morphology and cultural characters indistinguishable from those of *Salmonella typhimurium*, except some strains ferment maltose late or are anaerogenic.

Antigenic structure: [I], IV, XII: i: 1, 2, 3 . . . (Edwards, Jour. Hyg., *36*, 1936, 348). Many colonies may be examined before the specific phase flagellar antigen is demonstrated. Differs from *Salmonella typhimurium* in lacking antigen V.

Source: Isolated by Dr. McNee from a case of food poisoning in man, France, 1919.

Habitat: Natural host the pigeon, and may infect other animals, including man.

5. **Salmonella sp.** (Type Köln). (*Salmonella köln* Sievers, Cent. f. Bakt., I Abt., Orig., *150*, 1943, 52; *Salmonella coeln* Kauffmann, Acta Path. et Microbiol. Scand., Suppl. 54, 1944, 33.)

Antigenic structure: IV, V, XII: y: 1, 2, 3 . . .

Source: A single culture isolated from a human case of enteritis.

Habitat: Not reported from other sources as yet.

6. **Salmonella sp.** (Type Stanley). (*Bacillus paratyphosus B*, Stanley type, Schütze, Lancet, *1*, 1920, 93; *Salmonella stanleyi* Haupt, Ergebnisse d. Hyg., *13*, 1932, 673; *Salmonella* Stanley type, White, Med. Res. Council, Spec. Rept. Ser. 103, 1926, 19; *Salmonella stanley* Warren and Scott, Jour. Hyg., *29*, 1929, 415; Typus Stanley, Kauffmann, Ztschr. Hyg., *111*, 1930, 210.)

Antigenic structure: IV, V, XII: d: 1, 2 . . .

Source: Isolated from cases of human food poisoning in Stanley, England by Hutchens (1917).

Habitat: Not known as a natural pathogen of animals.

7. **Salmonella sp.** (Type Heidelberg). (*Bacterium enteritidis*, Typus Heidelberg, Habs, Cent. f. Bakt., I Abt., Orig., *130*, 1933, 367; *Salmonella heidelberg* Schutze et al., Jour. Hyg., *34*, 1934, 340.)

Antigenic structure: IV, V, XII: r: 1, 2, 3 . . .

Source: Isolated from cases of human food poisoning in Heidelberg, Germany.

Habitat: Not known as a natural pathogen of animals.

8. **Salmonella sp.** (Type Chester). (*Salmonella chester* Kauffmann and Tesdal, Ztschr. f. Hyg., *120*, 1937, 168.)

Antigenic structure: IV, [V], XII: e, h: e, n, x . . .

Source: Isolated by W. H. Grace, Chester, England, from gastroenteritis in man. Typed by Kauffmann and Tesdal (*loc. cit.*).

Habitat: Has usually been found in human feces.

9. **Salmonella sp.** (Type San Diego). (*Salmonella san diego* Kauffmann, Acta Path. et Microbiol. Scand., *17*, 1940, 429.)

Antigenic structure: IV, [V], XII: e, h: e, n, z_{15} . . .

Source: Originally isolated from cultures sent to Dr. Kauffmann by Dr. K. F. Meyer who obtained them from an outbreak of food poisoning near San Diego, California. Also reported from Denmark, Uruguay and Kentucky.

Habitat: Usually has been isolated from human feces, but has been found in birds and other animals.

10. **Salmonella sp.** (Type Salinas). (*Salmonella salinatis* Edwards and Bruner, Jour. Bact., *44*, 1942, 289.)

Antigenic structure: IV, XII: d, e, h: d, e, n, z_{15} . . .

By cultivation in semi-solid agar containing agglutinating serum for *Salmonella typhosa*, an organism having the antigenic formula for *Salmonella sp.* (Type San Diego) was isolated.

Source: From rat feces collected by Dr. Henry Welch near Salinas, California.

Habitat: Also found in normal human carriers.

11. **Salmonella sp.** (Type Saint Paul). (*Salmonella saint paul* Edwards and Bruner, Jour. Inf. Dis., *66*, 1940, 220.)

Antigenic structure: I, IV, V, XII: e, h: 1, 2, 3 . . .

Source: A single culture isolated from the liver of a turkey poult by Dr. B. S. Pomeroy, St. Paul, Minnesota. Two cases in man.

Habitat: Also reported from hogs.

11a. *Salmonella sp.* (Type Zagreb). (*Salmonella zagreb* Kauffmann, Acta Path. et Microbiol. Scand., *17*, 1940, 351.)

Antigenic structure: IV, V, XII: e, h: 1, 2. . . . This is a minor type of No. 11.

Source: Culture received by Dr. Kauffmann under the label *S. reading* from Dr. N. Cernozubov of Zagreb, Jugoslavia.

Habitat: Not reported from other sources as yet.

12. **Salmonella sp.** (Type Reading). (*Bacillus paratyphosus* B, Reading type, Schütze, Lancet, *1*, 1920, 93; *Salmonella reading* Schutze, Brit. Jour. Exp. Path., *11*, 1930, 34; Typus Reading, Kauffmann, Zentbl. f. d. ges. Hyg., *25*, 1931, 273; *Salmonella readingensis* Haupt, Ergebnisse d. Hyg., *13*, 1932, 673.)

Antigenic structure: IV, XII: e, h: 1, 5. . . .

Source: Isolated from the Reading, England water supply by Dr. H. Schütze. Also found in hogs (Edwards and Bruner, Jour. Inf. Dis., *72*, 1943, 64).

Habitat: A cause of gastroenteritis in man.

12a. *Salmonella sp.* (Type Kaposvar). (*Salmonella kaposvar* Rauss, Cent. f. Bakt., I Abt., Orig., *147*, 1941, 253; also see Kauffmann, Die Bakteriologie der Salmonella-Gruppe, Kopenhagen, 1941, 212.)

Antigenic structure: IV, V, XII: e, (h) 1, 5. . . . This is a minor type of No. 12.

Source: From the feces of three members of a family suffering from gastroenteritis.

Habitat: Not reported from other sources as yet.

13. **Salmonella sp.** (Type Kaapstad). (*Salmonella reading* var. *kaapstad* Henning, Rhodes and Gordon-Johnstone, Onderstepoort Jour. Vet. Sci. Animal Ind., *16*, 1941, 103; *Salmonella kaapstad* Kauffmann, Acta Path. et Microbiol. Scand., *19*, 1942, 523.)

Antigenic structure: IV, XII: e, h: 1, 7. . . .

Source: From a child with meningitis.

Habitat: Not known from other sources as yet.

14. **Salmonella sp.** (Type Derby). (*Bacillus enteritidis* Peckham, Jour. Hyg., *22*, 1923, 69; Derby type, Savage and White, Med. Res. Council Spec. Rept. Ser. 91, 1925, 19; *Salmonella derby* Warren and Scott, Jour. Hyg., *29*, 1929, 415; *Salmonella derbyensis* Haupt, Ergebnisse d. Hyg., *13*, 1932, 673.)

Antigenic structure: [I], IV, XII: f, g:—.

Source: Isolated from tank water at Derby, England.

Habitat: Widely distributed. Found in human feces, lymph glands of hogs, chickens, etc.

15. **Salmonella sp.** (Type Essen). (*Salmonella essen 173* Hohn and Herrmann, Cent. f. Bakt., I Abt., Orig., *135*, 1936, 505.)

Antigenic structure: IV, XII: g, m: —.

Source: Isolated from the feces of an infant, Essen, Germany.

Habitat: Known only from human sources.

16. **Salmonella sp.** (Type Budapest). (*Salmonella budapest* Rauss, Ztschr. f. Immunitätsf., *95*, 1929, 489.)

Antigenic structure: I, IV, XII: g, t:—.

Source: Originally isolated in Budapest from 3 normal persons and from 3 persons with enteric fever.

Habitat: Known only from human sources.

17. **Salmonella sp.** (Type California). (*Salmonella california* Edwards, Bruner and Hinshaw, Jour. Inf. Dis., *66*, 1940, 127; Hinshaw, Hilgardia, *13*, 1941, 583.)

Antigenic structure: IV, XII, g, m, t:—.

Source: Six cultures isolated from infected turkey poults from California. The seventh culture was isolated from a turkey in a second outbreak of the infection. Reported by Pomeroy and Fenstermacher (Jour. Amer. Vet. Med. Assoc., *94*, 1936, 90). Also found in hogs and man (Edwards and Bruner, Jour. Inf. Dis., *72*, 1943, 64).

Habitat: Also reported from chickens and ducks. Widely distributed.

18. **Salmonella sp.** (Type Brandenburg). (Typus-Brandenburg, Kauffmann and Mitsui, Ztschr. f. Hyg., *111*, 1930, 740; Kauffmann, Zentbl. f. d. ges. Hyg., *25*, 1931, 273; *Salmonella brandenburgensis* Haupt, Ergebnisse d. Hyg., *13*, 1932, 673; *Salmonella brandenburg* Schütze et al., Jour. Hyg., *34*, 1934, 540.)

Antigenic structure: IV, XII: l, v: e, n, z_{15}. . . . See Kauffmann, Ztschr. f. Hyg., *118*, 1936, 540.

Source: Isolated from a case of gastroenteritis at the Virchow Hospital of Berlin.

Habitat: Known only from human sources.

19. **Salmonella sp.** (Type Bispebjerg). (*Salmonella bispebjerg* Typus, Kauffmann, Ztschr. f. Hyg., *118*, 1936, 540.)

Antigenic structure: I, IV, XII: a: e, n, x. . . .

Source: Isolated from a case of gastroenteritis at the Bispebjerg Hospital in Copenhagen.

Habitat: Not reported from other sources as yet.

20. **Salmonella abortivoequina** (Good and Corbett) Bergey et al. (*Bacillus abortivus equinus* Good and Corbett, Jour. Inf. Dis., *13*, 1913, 53; *Bacillus abortus equi* Meyer and Boerner, Jour. Med. Res., *29*, 1913, 330; *Bacillus abortivo-equinus* Good and Corbett, Jour. Inf. Dis., *18*, 1916, 586; *Bacillus abortus equinus* Weiss and Rice, Jour. Med. Res., *35*, 1907, 403; *Bacillus abortivus* Winslow, Kligler and Rothberg, Jour. Bact., *4*, 1919, 477; *Bacillus abortus-equi* Holland, Jour. Bact., *5*, 1929, 216; *Bacterium abortum-equi* Holland, *ibid.*; Bergey et al., Manual, 1st ed., 1923, 217; *Bacillus enteritidis B*, *Typ. equinus* Januschke, Ztschr. f. Infektionskr. d. Haustiere, *29*, 1924, 182; *Salmonella abortus-equi* Bergey et al., Manual, 2nd ed., 1925, 236.) From Latin, aborting and equine.

Antigenic structure: IV, XII: —: e, n, x. . . .

Reduces trimethylamine oxide (Wood and Baird, *loc. cit.*).

Source: Isolated from afterbirth of mares that had aborted.

Habitat: A natural pathogen of mares, causing abortion. Infectious for guinea pigs, rabbits, goats, cows, producing abortion.

21. **Salmonella sp.** (Type Arechavaleta). (*Salmonella arechavaleta* Hormaeche and Peluffo, quoted from Hormaeche et al., Jour. Bact., *47*, 1944, 323.) Named in honor of Prof. Arechavaleta of Uruguay.

Antigenic structure: IV, [V], XII: a: 1, 7. . . .

Source: From a human case of gastroenteritis. Also found by Dr. P. R. Edwards among cultures sent to him from the Canal Zone for identification.

Habitat: Known only from human sources.

22. **Salmonella abortusovis** (Lovell) Schütze et al. (*Bacillus paratyphi abortus ovis* Schermer and Ehrlich, Cent. f. Bakt., I Abt., Ref., *73*, 1922, 252; *Bacillus enteritidis C*, *Typ. ovis* Januschke, Ztsch. f. Infektionskr. d. Haustiere, *27*, 1924, 182; *Bacterium abortus ovis* Lovell, Jour. Path. and Bact., *34*, 1931, 13; Typus-Abortus ovis, Kauffmann, Zentlbl. f. d. ges. Hyg., *25*, 1931, 273; Schütze et al., Jour. Hyg., *34*, 1934, 340.)

Antigenic structure: IV, XII: c: 1, 6. . . .

Reduces trimethylamine oxide (Wood and Baird, *loc. cit.*).

Source: Isolated from cases of abortion in sheep.

Habitat: Not known to infect any other animal.

23. **Salmonella sp.** (Type Altendorf). (*Salmonella altendorf* Hohn, Cent. f. Bakt., I Abt., Orig., *146*, 1940, 218.)

Antigenic structure: IV, XII: c: 1, 7. . . .

Source: Isolated from a case of acute gastroenteritis from Altendorf, Germany.

Habitat: Not reported from other sources as yet.

24. **Salmonella sp.** (Type Texas). (*Salmonella texas* Watt, De Capito and Moran, U. S. Public Health Repts., *62*, 1947, 808.)

Antigenic structure: IV, V, XII: k: e, n, z_{15}. . . .

Source: Isolated by Dr. James Watt from the feces of a boy convalescing from diarrhoea.

Habitat: Not reported from other sources as yet.

25. **Salmonella abortusbovis** Kauffmann. (Kauffmann, Ztschr. f. Hyg., *120*, 1937, 194.)

Antigenic structure: [I], IV, XXVII, XII: b: e, n, x. . . .

Liquefies gelatin (Kauffmann, Ztschr. f. Hyg., *117*, 1936, 778).

Source: Isolated and incompletely typed by H. Bernard, Ztschr. f. Hyg., *117*, 1935, 352.

Habitat: Normally found in cattle, causing abortion. Occasionally occurs in man.

26. **Salmonella sp.** (Type Bredeney). (*Salmonella bredeney* Kauffmann, Ztschr. f. Hyg., *119*, 1937, 356.)

Antigenic structure: I, IV, [XXVII], XII: l, v: 1, 7. . . .

Source: Found by Hohn and Herrmann in Bredeney, Germany. Typed by Kauffmann (*loc. cit.*). From cases of human gastroenteritis and an abscess of lower jaw.

Habitat: Isolated from human sources. Also found in normal hogs and chickens.

27. **Salmonella sp.** (Type Schleissheim). (*Salmonella schleissheim* Kauffmann and Tesdal, Ztschr. f. Hyg., *120*, 1937, 171.)

Antigenic structure: IV, XXVII, XII: b, z_{12}: —.

Liquefies gelatin (Kauffmann and Tesdal, *loc. cit.*).

Source: Isolated by Hopfengärtner (Münchener tierärz. Wchnschr., *1*, 1929, 185) in Schleissheim. From cattle. Typed by Kauffmann and Tesdal (*loc. cit.*). Also found by Tillmanns in the liver of a horse (Ztschr. f. Fleisch. u. Milch Hyg., *50*, 1940, 109). Caused an outbreak of gastroenteritis in 30 persons (Kauffmann, Acta Path. et Microbiol. Scand., *17*, 1940, 1).

Habitat: Apparently widely distributed.

28. **Salmonella sp.** (Type Schwarzengrund). (*Salmonella schwarzengrund* Kauffmann, Acta Path. et Microbiol. Scand., Suppl. 44, 1944, 34.)

Antigenic structure: I, IV, XXVII, XII: d: 1, 7.

Source: A single culture isolated by Dr. J. Hohn from a human case of enteritis that occurred in Schwarzengrund, near Breslau, Germany.

Habitat: Not reported from other sources as yet.

29. **Salmonella hirschfeldii** Weldin. (*Bacillus paratyphosus* β_5 Weil, Wien. klin. Wchnschr., *30*, 1917, 1061; *Bacillus erzinjan* Neukirch, Ztschr. f. Hyg., *85*, 1918, 103; Paratyphoid C bacillus, Hirschfeld, Lancet, *1*, 1919, 296; "Para-C", Mackie and Bowen, Jour. Roy. Army Med. Corps, *33*, 1919, 154; *Bacillus paratyphosus C* Andrewes and Neave, Brit. Jour. Exp. Path., *2*, 1921, 157; Paratyphus N_1, Iwaschenzoff, Arch. f. Schiffs- u. Trop. Hyg., *30*, 1926, 1; Weldin, Iowa Sta. Coll. Jour. Sci., *1*, 1927, 161; *Bacterium hirschfeldii* Weldin, *ibid.*, 161; Typus-Orient, Kauffmann, Zbl. f. d. ges. Hyg., *25*, 1931, 273; *Salmonella paratyphi C* Castellani and Chalmers, Man. Trop. Med., 3rd ed., 1919, 939; *Salmonella paratyphosus C* Castellani and Chalmers, *ibid.*, 952.) Named for Hirschfeld who worked with this organism.

Rods: 0.3 to 0.5 by 1.0 to 2.5 microns, occurring singly. Motile with peritrichous flagella. Gram-negative.

Gelatin colonies: Grayish, smooth, flat, glistening, margin irregular.

Gelatin stab: Flat, grayish surface growth. No liquefaction.

Agar colonies: Grayish, moist, smooth, translucent.

Broth: Turbid.

Litmus milk: Slightly acid, becoming alkaline.

Indole not formed.

Nitrites produced from nitrates.

Acid and gas from glucose, fructose, maltose, arabinose, xylose, dextrin, trehalose, mannitol, dulcitol and sorbitol. No action on lactose, sucrose,

salicin, adonitol or inositol. Rarely may fail to form gas from sugars (Nabih, Jour. Hyg., *41*, 1941, 39).

Reduces trimethylamine oxide (Wood and Baird, *loc. cit.*).

Hydrogen sulfide produced.

Optimum temperature 37°C.

Aerobic, facultative.

Antigenic structure: VI, VII, [Vi]: c: 1, 5. . . .

Source: Isolated from cases of enteric fever in man.

Habitat: A natural pathogen of man causing enteric fever.

30. **Salmonella choleraesuis** (Smith) Weldin. (Probably not the *Bacillus* of swine plague, Klein, Report of the Medical Officer of the Local Gov. Bd., England, 1877–78, Supplement, p. 168; *Bacterium* of swine plague, Salmon, U. S. Dept. Agr. Bur. An. Ind. Ann. Rep., 1885, 212; *Bacterium* of hog cholera, Salmon, *ibid.*, 1886, 20; Bakterium der Schweinepest, Selander, Cent. f. Bakt., *3*, 1888, 361; *Pasteurella salmoni* Trevisan, I generi e le specie delle Batteriacee, 1889, 21; *Bacterium cholerae suis* Th. Smith, U. S. Dept. Agr. Bur. An. Ind., Bull. 6, 1894, 9; Swine-feverbacillus, Klein, Cent. f. Bakt., I Abt., *18*, 1895, 105; *Bacillus suipestifer* Kruse, in Flügge, Die Mikroorganismen, 3 Aufl., *2*, 1896, 401; *Bacterium cholerae suum* Lehmann and Neumann, Bakt. Diag., 1 Aufl., *2*, 1896, 233; *Bacterium suipestifer* Chester, Ann. Rept. Del. Col. Agr. Exp. Sta., *9*, 1897, 70; *Bacillus cholerae suum* Migula, Syst. d. Bakt., *2*, 1900, 759; Le microbe du hog-cholera, Lignières, Bull. Soc. Cent. Méd. Vet., see Rec. de méd. vét., Paris, Sér. 8, *7*, 1900, 389; *Bacillus salmoni* Chester, Manual Determ. Bact., 1901, 210; *Bacterium intestinale suis* Le Blaye and Guggenheim, Manuel Pratique de Diagnostic Bacteriologique, 1914; *Bacillus suis* Krumwiede, Kohn and Valentine, Jour. Med. Res., *38*, 1918, 89; *Bacterium (Salmonella) cholera suis* Buchanan, Jour. Bact., *3*, 1918, 53; *Salmonella suipestifer* Castellani and Chalmers, Man. Trop. Med., 3rd ed., 1919, 939; *Bacillus cholerae-suis* Winslow, Kligler and Rothberg, Jour. Bact., *4*, 1919, 476; *Bacterium cholerae-suis* Holland, Jour. Bact., *5*, 1920, 217; *Bacillus paratyphosus B* (Arkansas type), Schütze, Lancet, *2*, 1920, 93; included in Group I *suipestifer*, Andrewes and Neave, Brit. Jour. Exp. Path., *2*, 1921, 157; Weldin, Iowa Sta. Coll. Jour. Sci., *1*, 1927, 155; Typus suipestifer Amerika, Kauffmann, Zbl. f. d. ges. Hyg., *25*, 1931, 273; the American *Salmonella suipestifer* of many authors.) From Latin, hog cholera.

Salmonella choleraesuis (Smith) Weldin is the type species of the genus *Salmonella*.

Rods: 0.6 to 0.7 by 2.0 to 3.0 microns, occurring singly. Motile with four to five peritrichous flagella. Gram-negative.

Gelatin colonies: Grayish, smooth, flat, glistening; margin irregular.

Gelatin stab: Flat, grayish surface growth. No liquefaction.

Agar colonies: Grayish, moist, smooth, translucent.

Agar slant: Grayish, moist, smooth, translucent growth.

Broth: Turbid, with thin pellicle and grayish-white sediment.

Litmus milk: Slightly acid, becoming alkaline, opalescent, translucent to yellowish-gray.

Potato: Grayish-white streak becoming brownish.

Indole not formed.

Nitrites produced from nitrates.

Acid and gas from glucose, fructose, galactose, mannose, xylose, maltose, glycerol, mannitol, dulcitol, rhamnose, sorbitol and dextrin. Arabinose, inositol, lactose, sucrose, salicin, inulin, raffinose and trehalose not attacked.

Reduces trimethylamine oxide (Wood and Baird, *loc. cit.*).

Hydrogen sulfide not produced.

Optimum temperature 37°C.

Aerobic, facultative.

Antigenic structure: VI, VII: c: 1,

5 . . . Serologically identical with *Salmonella typhisuis*, and cross-agglutinates to a varying degree with a number of other serotypes.

Habitat and source: Natural host the pig as an important secondary invader in the virus disease, hog cholera. Does not occur as a natural pathogen in other animals, although lethal for mice and rabbits on subcutaneous injection. Occasionally gives rise to acute gastroenteritis and enteric fever in man.

30a. *Salmonella choleraesuis* var. *Kunzendorf* Schütze et al.

The synonyms up to and including Weldin, 1927 for *Salmonella choleraesuis* apply equally well to the var. Kunzendorf, for these were not separated with certainty until 1926 (White, Med. Res. Council, London, Spec. Rep. Ser. 103, 27). Re-examined serologically a number of previously described strains agree with this variety. (Paratyphus C Bacillus, Heimann, Cent. f. Bakt., I Abt., Orig., *66*, 1912, 211; Paratyphosus C, Weil and Saxl, Wien. klin. Wchnschr., *30*, 1917, 519; Typus-suipestifer Kunzendorf, Pfeiler, Ztschr. f. Infektskr. d. Haust., *20*, 1920, 218; *Bacillus paratyphosus* B, G. type, Schütze, Lancet, *1*, 1920, 93; *Bacillus paratyphosus C*, Dudgeon and Urquart, Lancet, *2*, 1920, 15; included in Group II suipestifer, Andrewes and Neave, Brit. Jour. Exp. Path., *2*, 1921, 157 and Group V of Hecht-Johansen, Copenhagen, 1923; *Salmonella suipestifer* (European variety) Schütze, Brit. Jour. Exp. Path., *11*, 1930 34; *Typus-suipestifer* Kunzendorf, Kauffmann, Zbl. f. d. gen. Hyg., *25*, 1931, 273; *Salmonella choleraesuis* var. *kunzendorf* Schütze et al., Jour. Hyg., *34*, 1934, 341; the European *Salmonella suipestifer* of many authors.)

Indistinguishable from *Salmonella choleraesuis* in morphology and cultural characters, except that the Kunzendorf variety forms hydrogen sulfide.

Antigenic structure: VI, VII: [c]: 1, 5. Differs from *Salmonella choleraesuis* in lacking the specific flagellar phase; serologically identical with *Salmonella typhisuis* var. *voldagsen*.

Source: From pigs with swine fever and once from a monkey in captivity.

Habitat: Causes acute gastro enteritis and enteric fever in man. Also found in cattle, sheep, carnivora and chickens.

31. **Salmonella typhisuis** (Glässer) Schütze et al. (*Bacillus typhisuis* Glässer, Deutsche tierärztl. Wchnschr., *17*, 1909, 513; included in the Ferkeltyphus bacilli of German literature, Dammann and Stedefeder, Arch. f. wiss. u. prakt. Tierheilk., *36*, 1910, 432; *Bacillus glässer* Neukirch, Ztschr. f. Hyg., *85*, 1918, 103; *Bacterium typhi-suis* Holland, Jour. Bact., *5*, 1920, 221; included in Group I suipestifer, Andrewes and Neave, Brit. Jour. Exp. Path., *2*, 1921, 157; Typus-Glässer, Kauffmann, Zbl. f. d. ges. Hyg., *25*, 1931, 273; Schütze et al., Jour. Hyg., *34*, 1934, 342.) From Greek, typhus and Latin, pig.

Rods: 0.6 to 0.7 by 2.0 to 3.0 microns, occurring singly. Motile with four to five peritrichous flagella. Gram-negative.

Gelatin colonies: Grayish, smooth, flat, glistening, edge entire. No liquefaction.

Agar colonies: Grayish, moist, smooth, translucent.

Broth: Turbid.

Litmus milk: Slightly acid or neutral.

Indole not formed.

Nitrites produced from nitrates.

Forms gas slowly and sparsely from all substances. Growth poor on all ordinary media.

Acid from arabinose, xylose and trehalose. Delayed or variable fermentation from dextrin, maltose, rhamnose, dulcitol, sorbitol. Mannitol not fermented or very slowly. Inositol not fermented.

No H_2S produced.

Optimum temperature 37°C.

Aerobic, facultative.

Antigenic structure: Identical with *Salmonella choleraesuis*, from which the

organism differs in respect to arabinose and trehalose. Antigenic structure VI, VII: c: 1, 5. . . .

Habitat: Infects only the pig.

31a. *Salmonella typhisuis* var. *voldagsen* Schütze et al. (Included in Ferkeltyphus bacilli, Dammann and Stedefeder, Arch. f. wiss. u. prakt. Tierheilk., *36*, 1910, 432; *Bacillus voldagsen* Neukirch, Ztschr. f. Hyg., *85*, 1918, 103; included in Group II suipestifer, Andrewes and Neave, Brit. Jour. Exp. Path., *2*, 1921, 157; Typus-voldagsen, Kauffmann, Zbl. f. d. ges. Hyg., *25*, 1931, 273; *Salmonella typhisuis* var. *voldagsen*, Schütze et al., Jour. Hyg., *34*, 1934, 342.)

Morphology and cultural characters identical with those of *Salmonella typhisuis*.

Antigenic structure: VI, VII: [c]: 1, 5. . . . Identical with that of *Salmonella choleraesuis* var. *Kunzendorf* from which species the organism differs culturally.

Habitat: Infects only the pig.

32. **Salmonella sp.** (Type Thompson). (Thompson type of *Salmonella*, Scott, Jour. Hyg., *25*, 1925, 398; Typus-Thompson-Berlin, Kauffmann, Zbl. f. d. ges. Hyg., *25*, 1931, 273; *Salmonella thompson* Schütze et al., Jour. Hyg., *34*, 1934, 343.) Named after the family involved in the outbreak.

Antigenic structure, VI, VII: k: 1, 5. . . .

Source: Isolated from food poisoning in man. Also found in chickens and turkeys (Edwards and Bruner, Jour. Inf. Dis., *72*, 1943, 64).

Habitat: Widely distributed in warm-blooded animals.

32a. *Salmonella sp.* (Type Berlin) (Type Thompson). (Typus-Berlin, Kauffmann, Cent. f. Bakt., I Abt., Ref., *94*, 1929, 282; Typus C Berlin, Boecker and Kauffmann, Cent. f. Bakt., I Abt., Orig., *116*, 1930, 458; Typus-Thompson-Berlin, Kauffmann, Zbl. f. d. ges. Hyg., *25*, 1931, 273; *Salmonella thompson* var. *berlin* Schütze et al., Jour. Hyg., *34*, 1934, 343.)

Antigenic structure: VI, VII: [k]: 1, 5. . . .

Source: Isolated from food poisoning in man. Not known to be a natural pathogen of animals.

Habitat: A natural pathogen of man causing food poisoning.

33. **Salmonella sp.** (Type Montevideo). (*Salmonella montevideo* Hormaeche and Peluffo, Arch. Urug. de Med., Cirug. y Espec., *9*, 1936, 673.)

Antigenic structure: VI, VII: g, m, s: —.

Source: Originally isolated from human sources in Montevideo from an ape that died of an enterocolitis, and mesenteric glands of healthy hogs; also reported from chickens and powdered eggs (Schneider, Food Research, *11*, 1946, 313).

Habitat: Apparently widely distributed.

34. **Salmonella sp.** (Type Oranienburg). (Typus-Oranienburg, Kauffmann, Ztschr. f. Hyg., *111*, 1930, 223; *Salmonella oranienburgensis* Haupt, Ergebnisse der Hyg., *13*, 1932, 673; *Salmonella oranienburg* Schütze et al., Jour. Hyg., *34*, 1934, 343.)

Antigenic structure: VI, VII: m, t: —.

Source: From the feces of a child in a children's home near Oranienburg. Later isolated from gastroenteritis in man. Also from quail, chickens and powdered eggs (Schneider, *loc. cit.*).

Habitat: Reported from human sources, from hogs and from birds.

35. **Salmonella sp.** (Type Virchow). (Typus-Virchow, Kauffmann, Ztschr. f. Hyg., *111*, 1930, 221; *Salmonella virchowii* Haupt, Ergebnisse der Hyg., *13*, 1932, 673; *Salmonella virchow* Schütze et al., Jour. Hyg., *34*, 1934, 343.)

Antigenic structure: VI, VII: r: 1, 2, 3. . . .

Source: Isolated from food poisoning in a man at the Rudolf Virchow Hospital in Berlin.

Habitat: A natural pathogen of man causing food poisoning.

36. **Salmonella sp.** (Type Oslo). (*Salmonella oslo* Tesdal, Ztschr. f. Hyg., *119*, 1937, 451.)

Antigenic structure: VI, VII: a: e, n, x. . . .

Source: Isolated in Oslo, Norway from cases of gastroenteritis in man.

Habitat: Not reported from other sources as yet.

37. **Salmonella sp.** (Type Amersfoort). (*Salmonella amersfoort* Henning, Jour. Hyg., *37*, 1937, 561.)

Antigenic structure: VI, VII: d: e, n, x. . . .

Source: Originally isolated from chickens from Amersfoort, Transvaal. Later found in a human mixed infection with *Salmonella typhi murium*.

Habitat: Not reported from other sources as yet.

38. **Salmonella sp.** (Type Braenderup). (*Salmonella braenderup* Kauffmann and Henningsen, Ztschr. f. Hyg., *120*, 1937, 640.)

Antigenic structure: VI, VII: e, h: e, n, z_{15}. . . .

Source: Isolated from a case of human gastroenteritis in Braenderup, Denmark. Also from a cat in the same home that had died from a diarrhoea. Reported later from So. Africa (see Kauffmann, Die Bakteriologie der Salmonella-Gruppe, Kopenhagen, 1941, 237).

Habitat: Apparently widely distributed.

39. **Salmonella sp.** (Type Potsdam). (Typus-Potsdam, Kauffmann and Mitsui, Ztschr. f. Hyg., *111*, 1930, 740; *Salmonella potsdamensis* Haupt, Ergebnisse der Hyg., *13*, 1932, 673; *Salmonella potsdam* Schütze et al., Jour. Hyg., *34*, 1934, 343.)

Antigenic structure: VI, VII: l, v: e, n. z_{15}. . . .

Source: Isolated from food poisoning in man at Potsdam, Germany.

Habitat: A natural pathogen of man causing food poisoning.

40. **Salmonella sp.** (Type Bareilly). (*Salmonella*, Type Bareilly, Bridges and Scott, Jour. Roy. Army Med. Corps, *56*, 1931, 241; *Salmonella bareilly* Schütze et al., Jour. Hyg., *34*, 1934, 343.)

Antigenic structure: VI, VII: y: 1, 5. . . .

Source: Isolated in 1928 from cases of mild enteric fever that occurred in Bareilly, India. Also reported from chickens (Kauffmann, Die Bakteriologie der Salmonella-Gruppe, Kopenhagen, 1942, 235).

Habitat: A natural pathogen of man causing gastroenteritis and enteric fever. Widely distributed in fowls.

41. **Salmonella sp.** (Type Hartford). (*Salmonella hartford* Edwards and Bruner, Jour. Inf. Dis., *69*, 1941, 223.)

Antigenic structure: VI, VII: y: e, n, x. . . .

Source: One culture isolated from the stool of a man with persistent diarrhoea by Dr. E. K. Borman, Hartford, Conn.

Habitat: Not reported from other sources as yet.

42. **Salmonella sp.** (Type Mikawasima*). (*Salmonella bareilly* var. *mikawasima* Hatta, Japan Jour. Exper. Med., *16*, 1938, 201; *Salmonella mikawasima* Hormaeche, quoted from Schütze et al., Proc. 3rd Internat. Cong. Microbiol., 1940, 337; also see Kauffmann, Acta Path. et Microbiol. Scand., *16*, 1939, 347 and *ibid.*, *17*, 1940, 429.)

Antigenic structures: VI, VII: y: e, n, z_{15}. . . .

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*Correct spelling according to Prof. Kojima.

Source: Isolated from a rat by Prof. Kojima and Prof. Hatta, 1937.

Habitat: Not reported from other sources as yet.

43. **Salmonella sp.** (Type Tennessee). (*Salmonella tennessee* Bruner and Edwards, Proc. Soc. Exp. Biol. and Med., *50*, 1942, 174.)

Antigenic structure: VI, VII: z_{29}: —.

Source: Culture isolated from feces of normal carrier by Dr. W. C. Williams, State Dept. of Health, Nashville, Tennessee.

Habitat: Also reported from turkeys and powdered eggs.

44. **Salmonella sp.** (Type Concord). (*Salmonella* var. *concord* Edwards and Hughes, Jour. Bact., *47*, 1944, 574.)

Antigenic structure: VI, VII: l, v: 1, 2, 3. . . .

Source: Two cultures isolated by Dr. J. R. Beach and one by Dr. C. U. Duckworth from fatal infections in chicks (U. S. A.) and one by Dr. Joan Taylor from the stool of a person affected with gastroenteritis (England).

Habitat: Also reported from turkeys.

45. **Salmonella sp.** (Type Infantis). (*Salmonella infantis* Wheeler and Borman, Jour. Bact., *46*, 1943, 481.)

Antigenic structure: VI, VII: r: 1, 5. . . .

Source: Isolated at Hartford, Connecticut from the blood of an infant. Subsequently also from stools.

Habitat: Not reported from other sources as yet.

46. **Salmonella sp.** (Type Georgia). (*Salmonella georgia* Morris, Brim and Sellers, Amer. Jour. Pub. Health, *34*, 1944, 1279; Seligmann, Saphra and Wassermann, Amer. Jour. Hyg., *40*, 1944, 227.)

Antigenic structure: VI, VII: b: e, n, z_{15}. . . .

Source: Isolated by Miss Jane Morris from the feces of a 16-year-old boy during routine examination of food handlers, State Dept. of Health, Atlanta, Georgia.

Habitat: Not reported from other sources as yet.

47. **Salmonella sp.** (Type Papua). (*Salmonella papuana* Wilcox, Edwards and Coates, Jour. Bact., *49*, 1945, 514.)

Antigenic structure: VI, VII: r: e, n, z_{15}. . . .

Source: Isolated by Lt. Goldwasser from human feces from Port Moresby in Papua, New Guinea.

Habitat: Not reported from other sources as yet.

48. **Salmonella sp.** (Type Richmond). (*Salmonella richmond* Moran and Edwards, Proc. Soc. Exp. Biol. and Med., *62*, 1946, 294.)

Antigenic structure: VI, VII: y: 1, 2, 3. . . .

Source: Isolated by Mr. Forest Spindle in Richmond, Virginia from the feces of a child affected with gastroenteritis.

Habitat: Isolated as yet from human sources only.

49. **Salmonella sp.** (Type Cardiff). (*Salmonella cardiff* Taylor, Edward and Edwards, Brit. Med. Jour., 1945, i, 368.)

Antigenic structure: VI, VII: k: 1, 10. . . .

Source: Isolated from human case of gastroenteritis from Cardiff, Wales.

Habitat: Isolated as yet from human sources only.

50. **Salmonella sp.** (Type Daytona). (*Salmonella daytona* Moran and Edwards, Proc. Soc. Exp. Biol. and Med., *62*, 1946, 294.)

Antigenic structure: VI, VII: k: 1, 6. . . .

Source: Isolated by Mrs. Mildred Galton from human feces from Daytona, Florida.

Habitat: Not known from other sources as yet.

51. **Salmonella sp.** (Type Newport). (Paratyphus β_2, Weil and Saxl, Wien. klin. Wchnschr., *30*, 1917, 519; *Bacillus paratyphosus B*, Newport type, Schütze, Lancet, *1*, 1920, 93; Paratyphus Newport Bacillus, Kauffmann, Cent. f. Bakt., I Abt., Ref., *94*, 1929, 282; *Salmonella newport* Schütze, Brit. Jour. Exp. Path., *11*, 1930, 34; *Salmonella newportensis* Haupt, Ergebnisse der Hyg., *13*, 1932, 673.)

Antigenic structure: VI, VIII: e, h: 1, 2, 3. . . .

Source: Isolated from food poisoning in man, Newport, England.

Habitat: Widely distributed in man, cattle, hogs, chickens, etc. Also in snakes (Hinshaw and McNeil, Amer. Jour. Vet. Res., *6*, 1945, 264).

51a. *Salmonella sp.* (Type Puerto Rico) Kauffmann. (Jordan, Amer. Jour. Trop. Dis., *14*, 1934, 27; Kauffmann, Cent. f. Bakt., I Abt., Orig., *132*, 1934, 162; Schütze et al., Jour. Hyg., *34*, 1934, 344.)

Antigenic structure: VI, VIII: [e, h]: 1, 2, 3. . . .

This is regarded as a non-specific variant of *Salmonella sp.* (Type Newport) by Schütze et al. (Proc. 3rd Internat. Cong. Microbiol., New York, 1940, 833).

52. **Salmonella sp.** (Type Pueris). (*Salmonella pueris* Wheeler and Borman, Jour. Bact., *46*, 1943, 481.)

Antigenic structure: VI, VIII: e, h: 1, 2. . . .

Source: Isolated at Hartford, Connecticut from anal swabbings of a 14-year-old boy during an attack of gastroenteritis complicating measles.

Habitat: Not reported from other sources as yet.

53. **Salmonella sp.** (Type Kottbus). (*Salmonella newport* var. *kottbus* Kauffmann, Cent. f. Bakt., I Abt., Orig., *132*, 1934, 162; *Salmonella kottbus* Schütze et al., Proc. 3rd Internat. Microbiol. Cong., New York, 1940, 834.)

Antigenic structure: VI, VIII: e, h: 1, 5. . . .

Source: From an acute case of gastroenteritis in Kottbus, Denmark.

Habitat: Not reported from other sources as yet.

54. **Salmonella sp.** (Type Muenchen). (Typus München, Mandelbaum, Cent. f. Bakt., I Abt., Ref., *105*, 1932, 377; *Salmonella muenchen* Schütze et al., Jour. Hyg., *34*, 1934, 344.)

Antigenic structure: VI, VIII: d: 1, 2. . . .

Source: Isolated from a fatal case of enteric fever.

Habitat: Widely distributed. Reported from man, rabbits, hogs, camels and chickens (Kauffmann, Die Bakteriologie der Salmonella Gruppe, 1941, 244).

54a. *Salmonella sp.* (Type Oregon). (*Salmonella oregon* Edwards and Bruner, Amer. Jour. Hyg., *34*, 1941, 21.)

Antigenic structure: VI, VIII: d: 1, 2, 3. . . .

Source: Six cultures, one isolated from a turkey by Dr. E. M. Dickinson and five from the mesenteric glands of apparently normal hogs by Dr. H. L. Rubin. This is a minor type of No. 54.

Habitat: Also reported from reptiles, chickens and man. Also powdered eggs.

55. **Salmonella sp.** (Type Manhattan). (*Salmonella manhattan* Edwards and Bruner, Amer. Jour. Hyg., *34*, 1941, 21.)

Antigenic structure: VI, VIII: d:, 1, 5. . . .

Source: Two cultures, one isolated from a chicken by Dr. L. D. Bushnell, Manhattan, Kansas, and the other from a turkey by Dr. W. R. Hinshaw. Also

from reptiles, hogs and human sources (Edwards and Bruner, Jour. Inf. Dis., *72*, 1942, 64).

Habitat: Apparently widely distributed.

56. **Salmonella sp.** (Type Litchfield). (*Salmonella litchfield* Edwards and Bruner, Jour. Inf. Dis., *66*, 1940, 220.)

Antigenic structure: VI, VIII: l, v: 1, 2, 3. . . .

Source: Isolated from the liver of a young turkey poult from Litchfield, Minnesota by Dr. B. S. Pomeroy. Also isolated from a case of food poisoning in man by Miss Georgia Cooper.

Habitat: Not reported from any other source, as yet.

57. **Salmonella morbificans** (Migula) Haupt. (*Bacillus bovis morbificans* Basenau, Arch. f. Hyg., *20*, 1894, 257; *Bacillus morbificans bovis* Kruse, in Flügge, Die Mikroorganismen, 3 Aufl., *2*, 1896, 380; *Bacterium morbificans bovis* Chester, Ann. Rept. Del. Col. Agr. Exp. Sta., *9*, 1897, 70; *Bacillus morbificans* Migula, Syst. d. Bakt., *2*, 1900, 747; *Flavobacterium morbificans* Bergey et al., Manual, 3rd ed., 1930, 147; Haupt, Ergebnisse der Hyg., *13*, 1930, 673; *Salmonella bovis-morbificans* Schütze et al., Jour. Hyg., *34*, 1934, 344.)

Antigenic structure: VI, VIII: r: 1, 5. . . .

Source: Originally isolated from a septicemia in a cow.

Habitat: Also found in rabbits and in gastroenteritis in man.

58. **Salmonella sp.** (Type Narashino). (*Salmonella narashino* Nakaguro and Yamashita, quoted from Kauffmann, Die Bakteriologie der Salmonella-Gruppe, Kopenhagen, 1941, 246.)

Antigenic structure: VI, VIII: a: e, n, x. . . .

Source: From the blood and feces of a person suffering from enteric fever. Found in Japan.

Habitat: Not reported from other sources as yet.

59. **Salmonella sp.** (Type Buenos Aires). (*Salmonella bonariensis* Monteverde, Nature, *149*, 1942, 472.)

Antigenic structure: VI, VIII: i: e, n, x. . . .

Source: Isolated by Dr. Monteverde, Buenos Aires from a mesenteric gland of a normal hog.

Habitat: Also reported from normal human carriers and from cases of gastroenteritis.

60. **Salmonella sp.** (Type Glostrup). (*Salmonella glostrup* Kauffmann and Henningsen, Acta Path. et Microb. Scand., *16*, 1939, 99.)

Antigenic structure: VI, VIII: z_{10}: e, n, z_{15}. . . .

Source: Isolated from cases of gastroenteritis in a family in Denmark. Also affected their dog. Later isolated in Jugoslavia and in Palestine.

Habitat: Evidently widely distributed.

61. **Salmonella sp.** (Type Duesseldorf). (*Salmonella duesseldorf* Hohn, Cent. f. Bakt., I Abt., Orig., *146*, 1940, 218.)

Antigenic structure: VI, VIII: z_4, z_{24}: —.

Source: Isolated from two patients, one of whom died. Found in Duesseldorf, Germany.

Habitat: Not reported from other sources as yet.

62. **Salmonella sp.** (Type Tallahassee). (*Salmonella tallahassee* Moran and Edwards, Proc. Soc. Exp. Biol. and Med., *62*, 1946, 294.)

Antigenic structure: VI, VIII: z_4, z_{32}: —.

Source: Isolated by Mrs. Mildred Gal-

ton from feces of gastroenteritis patients and from normal human carriers, Tallahassee, Florida.

Habitat: Not known from other sources.

63. **Salmonella sp.** (Type Gatun). (*Salmonella gatuni* Wilcox and Coates, Jour. Bact., *51*, 1946, 561.)

Antigenic structure: VI, VIII: b: e, n, x. . . .

Source: Isolated from human feces from Gatun, Canal Zone.

Habitat: Not known from other sources as yet.

64. **Salmonella sp.** (Type Amherst). (*Salmonella amherstiana* Edwards and Bruner, Jour. Immunol., *44*, 1942, 319.)

Antigenic structure: (VIII): l, v: 1, 6. . . .

Source: Isolated by Dr. H. Van Roekel from one of a group of poults affected with a fatal disease.

Habitat: Not reported from other sources as yet.

65. **Salmonella sp.** (Type Virginia). (*Salmonella virginia* Saphra and Seligmann, Proc. Soc. Exper. Biol. and Med., *58*, 1945, 50.)

Antigenic structure: (VIII): d: —.

Source: Isolated by F. Spindle, Richmond, Virginia from the feces of an adult person suffering from a diarrhoea.

Habitat: Not known from other sources as yet.

66. **Salmonella typhosa** (Zopf) White. (Bacillus des Abdominal-Typhus, Eberth, Arch. f. path. Anat., *81*, 1880 and *83*, 1881; Typhus bacillen, Gaffky, Mitteil. a. d. kaiserl. Gesundheitsamte, *2*, 1884, 372; *Bacillus typhosus* Zopf, Die Spaltpilze, 3 Aufl., 1885, 126; not *Bacillus typhosus* Klebs, Handbuch d. path. Anat., 1880; *Bacillus typhi* Schroeter, in Cohn, Kryptogamen Flora v. Schlesien, *3*, 1886, 165; *Bacillus typhi abdominalis* Flügge, Die Mikroorganismen, 2 Aufl., 1886, 198; *Vibrio typhosus* Trevisan, I generi e le specie delle Batteriacee, 1889, 23; *Bacterium typhi* Chester, Ann. Rept. Del. Col. Agr. Exp. Sta., *9*, 1897, 73; *Bacterium typhosum* Twort, Proc. Royal Soc., London, *79*, B, 1907, 329; *Acystia typhi* Enderlein, Sitzber. Gesell. Naturf. Freunde, Berlin, 1917, 517; *Bacterium (Eberthella) typhi* Buchanan, Jour. Bact., *3*, 1918, 53; *Eberthus typhosus* Castellani and Chalmers, Man. Trop. Med., 3rd ed., 1919, 936; *Eberthella typhi* Bergey et al., Manual, 1st ed., 1923, 223; *Eberthella typhosa* Weldin, Iowa State College Jour. Sci., *1*, 1927, 170; *Salmonella typhi* Warren and Scott, Jour. Hyg., *29*, 1930, 416; White, Jour. Hyg., *29*, 1930, 443.) Named from the disease, typhoid fever.

The species name *typhosa* should be used for the typhoid organism when it is placed in any genus other than *Bacillus* in spite of the earlier use of this species name by Klebs for a different organism. There are two reasons for this: (a) This appears to be the proper course to follow under International Rules of Nomenclature (See Art. 54, p. 54) and (b) there is less chance for confusion regarding the nature of this organism among English-speaking persons who may carelessly interpret *typhi* as the name of a typhus rather than a typhoid bacillus.

Rods: 0.6 to 0.7 by 2.0 to 3.0 microns, occurring singly, in pairs, occasionally short chains. Motile with peritrichous flagella. Gram-negative.

Gelatin colonies: Grayish, transparent to opaque, with leaf-like surface markings.

Gelatin stab: Thin, white, opalescent growth. No liquefaction.

Agar colonies: Grayish, transparent to opaque.

Agar slant: Whitish-gray, glistening, echinulate, entire to undulate growth

Broth: Turbid, moderate sediment and delicate pellicle in old cultures.

Litmus milk: Slight, transient acidity, followed by a return to neutral or to slight alkalinity.

Potato: Delicate, moist, slightly spreading, barely visible growth.

Acid but no gas from glucose, fructose, galactose, xylose, maltose, raffinose, dextrin, glycerol, mannitol and sorbitol. No action on lactose, sucrose, inulin, rhamnose, inositcl, salicin and usually arabinose and dulcitol.

Reduces trimethylamine oxide (Wood and Baird, *loc. cit.*).

Indole not formed.

No characteristic odor.

Nitrites produced from nitrates.

Hydrogen sulfide produced.

Aerobic, facultative.

Optimum temperature 37°C.

Antigenic structure: IX, XII, [Vi]: d: —. The somatic antigens are related to those of *Salmonella enteritidis* and a number of other species of *Salmonella*. V and W forms are present (Felix and Pitt, Jour. Path. and Bact., *38*, 1934, 409; Craigie and Brandon, Jour. Path. and Bact., *43*, 1936, 233 and 239). Craigie and Yen (Canadian Public Health Journal, *29*, 1938, 448 and 484) by the action of selected Vi phages recognize eleven distinct stable types of *Salmonella typhosa* which have been found to be of epidemiological importance.

Source: From the human intestine.

Habitat: The cause of typhoid fever. Pathogenic for laboratory animals on parenteral injection. Isolated once from a chicken by Henning, Onderstepoort, So. Africa.

Note: This species has previously been regarded as the type species of the genus *Eberthella* Buchanan (*Acystia* Enderlein, Sitzber. Gesell. Naturf. Freunde, Berlin, 1917, 317; Buchanan, Jour. Bact., *3*, 1918, 53; *Eberthus* Castellani and Chalmers, Man. Trop. Med., 3rd ed., 1919, 934; *Lankoides* Castellani and Chalmers, *ibid.*, 938; *Wesenbergus* Castellani and Chalmers, *ibid.*, 940.)

67. **Salmonella enteritidis** (Gaertner) Castellani and Chalmers. (*Bacillus enteritidis* Gaertner, Correspond. d. Allgemein. Artzl. Verein Thuringen, *17*, 1888, 573; *Klebsiella enteritidis* De Toni and Trevisan, in Saccardo, Sylloge Fungorum, *8*, 1889, 923; *Bacterium enteritidis* Chester, Ann. Rept. Del. Col. Agr. Exp. Sta., *9*, 1897, 68; *Bacillus gaertner* Morgan, Brit. Med. Jour., *1*, 1905, 1257; Castellani and Chalmers, Manual Trop. Med., 3rd ed., 1919, 930.) Named for the disease, enteritis.

Rods: 0.6 to 0.7 by 2.0 to 3.0 microns, occurring singly, in pairs and occasionally in short chains. Motile with peritrichous flagella. Gram-negative.

Gelatin colonies: Circular, gray, translucent, granular, entire.

Gelatin stab: Abundant surface growth. No liquefaction.

Agar colonies: Circular, gray, translucent, moist, smooth, entire. Deskowitz and Buchbinder (Jour. Bact., *29*, 1935, 294) describe a variant that produces a soluble yellow pigment where certain peptone is present in the agar. Antigenic structure not determined.

Agar slant: Grayish-white, opalescent, smooth, moist, undulate growth.

Broth: Turbid, with thin pellicle and grayish-white sediment.

Litmus milk: Slightly acid, becoming alkaline, opalescent, translucent to yellowish-gray.

Potato: Abundant, moist, yellowish-brown to brown growth.

Indole not formed.

Nitrites produced from nitrates.

Acid and gas from glucose, fructose, galactose, mannose, arabinose, xylose, maltose, trehalose, dextrin, glycerol, mannitol, dulcitol and sorbitol. No acid or gas from lactose, sucrose, inulin, salicin, raffinose, adonitol and inositol.

Reduces trimethylamine oxide (Wood and Baird, *loc. cit.*).

Hydrogen sulfide produced.

No characteristic odor.

Aerobic, facultative.

Optimum temperature 37°C.

Antigenic structure: [I], IX, XII: g, m: —.

Source: First isolated from feces in an epidemic of meat poisoning at Frankenhausen, Germany.

Habitat: Widely distributed, occurring in man. Also in domestic and wild animals, particularly rodents.

67a. *Salmonella enteritidis* var. *Danysz.* (Bahr, Deutsche tierärztl. Wchnschr., 1928, 786 and 1930, 145; Typus-Gärtner Ratin, Kauffmann, Zbl. f. d. ges. Hyg., *25*, 1931, 273; *Salmonella enteritidis* var. *danysz*, Schütze et al., Jour. Hyg., *34*, 1934, 345; *Salmonella danysii* Gay et al., Agents of Disease and Host Resistance, 1935, 650.)

Differs from *Salmonella enteritidis* only in its negative action on glycerol in Stern's medium.

Source: Isolated by Danysz in 1900.

Habitat: A natural pathogen of rodents and man.

67b. *Salmonella enteritidis* var. *Chaco.* (Savino and Menendez, Rev. Inst. Bact., *6*, 1934, 347; Kauffmann, Ztschr. f. Hyg., *117*, 1935, 401.)

Differs from *Salmonella enteritidis* in its action on dulcitol when tested by the method of Bitter, Weigmann and Habs (Münch. med. Wchnschr., *73*, 1926, 940.)

Habitat and source: Isolated from cases of fever during the Chaco war, South America.

67c. *Salmonella enteritidis* var. *Essen.* (Hohn and Herrmann, Cent. f. Bakt., I Abt., Orig., *133*, 1935, 183; *ibid.*, *134*, 1935, 277; Kauffmann, Ztschr. f. Hyg., *117*, 1935, 401.)

Differs from *Salmonella enteritidis* when tested by the method of Bitter, Weigmann and Habs (Münch. med. Wchnschr., *73*, 1926, 940), giving a negative reaction with arabinose and dulcitol.

Habitat and source: Isolated from human gastroenteritis, ducks and duck eggs.

NOTE: Jansen (Cent. f. Bakt., I Abt., Orig., *135*, 1935, 421) states that the organism named by him *Salmonella enteritidis* var. *Mulheim* is in reality *Salmonella enteritidis* var. *Essen.*

67d. *Salmonella enteritidis* var. *Jena.* (Fournier, Rev. Immunolog., Paris, *6*, 1940–41, 264.)

Source: Isolated from purulent pleural fluid.

Habitat: Not reported from other sources as yet.

68. **Salmonella sp.** (Type Dublin). (*Bacillus enteritidis* Pesch, Cent. f. Bakt., I Abt., Orig., *98*, 1926, 22; Dublin Type, White, Med. Res. Counc., Syst. of Bact., *4*, 1929, 86 and White, Jour. Hyg., *29*, 1930, 443; *Salmonella dublin* Warren and Scott, Jour. Hyg., *29*, 1930, 415; Typus-Dublin-Kiel, Kauffmann, Zbl. f. d. ges. Hyg., *25*, 1931, 273; *Salmonella enteritidis* var. *dublin* Schütze et al., Jour. Hyg., *34*, 1934, 345.)

Antigenic structure: I, IX, XII: g, p: —.

Source: From meningitis in children (Pesch, *loc. cit.*). Also isolated by Dr. J. W. Bigger in Dublin, Eire from a fatal fever following a kidney operation. Typed by Dr. Bruce White (*loc. cit.*).

Habitat: Found in man. A natural pathogen of cattle. Widely distributed in cattle and foxes.

Two special fermentative types belong here: (1) *Salmonella dublin 2* = *Salmonella dublin* var. *accra* Kauffmann, (2) *Salmonella dublin 3* = *Salmonella dublin* var. *koeln* Kauffmann (Die Bakteriologie der Salmonella-Gruppe, Kopenhagen, 1941, 252).

69. **Salmonella sp.** (Type Rostock). (Gärtner-Poppe Typus, Bahr, Dtsch. Tierärzt. Wchnschr., 1930, 145; Typus

Gärtner-Rostock, Kauffmann, Ztschr. f. Hyg., *111*, 1930, 221; *Salmonella enteritidis* var. *rostock* Schütze et al., *34*, 1934, 345; *Salmonella rostockensis* Haupt, Ergebnisse der Hyg., *13*, 1932, 673.)

Antigenic structure: I, IX, XII: g, p, u: —.

Source: Originally isolated from cattle by Dr. Poppe in Rostock, Germany.

Habitat: Not known to infect man.

70. **Salmonella sp.** (Type Moscow). (Paratypus C_1, Weigmann, Cent. f. Bakt., I Abt., Orig., *97*, 1925, Beiheft, 299; *Salmonella* Type Moscow, Hicks, Jour. Hyg., *29*, 1929, 446; *Salmonella moscow* Warren and Scott, Jour. Hyg., *29*, 1929, 446; Typus Gärtner-Moskow, Kauffmann, Ztschr. f. Hyg., *111*, 1930, 229; *Salmonella moscowaensis* Haupt, Ergebnisse der Hyg., *13*, 1932, 673; *Salmonella enteritidis* var. *moscow*, Schütze et al., *34*, 1934, 345).

Antigenic structure: IX, XII: g, q: —.

Source: From patients with enteric fever. Isolated in Moscow, Russia.

Habitat: Infects man, horses, cattle.

71. **Salmonella sp.** (Type Blegdam). (*Salmonella blegdam* Kauffmann, Ztschr. f. Hyg., *117*, 1935, 431.)

Antigenic structure: IX, XII: g, m, q: —.

Source: Isolated in 1929, at State Serum Institute, Copenhagen from the blood of a pneumonia patient. Also found in the blood of a patient by Dr. Fournier, in Shanghai, China (Kauffmann, Die Bakteriologie der Salmonella-Gruppe, Kopenhagen, 1941, 264).

Habitat: Not reported from other sources as yet.

72. **Salmonella sp.** (Type Berta). (*Salmonella berta* Hormaeche, Peluffo and Salsamendi, Arch. Urug. de Med., Cirug. y Espec., *12*, 1938, 277.) Named in honor of Prof. Arnoldo Berta, Uruguay.

Antigenic structure: IX, XII: f, g, t: —.

Source: Isolated from the mesenteric glands of normal hogs.

Habitat: Causes gastroenteritis in man. Also found in chickens.

73. **Salmonella sp.** (Type Pensacola). (*Salmonella pensacola* Moran and Edwards, Proc. Soc. Exper. Biol. and Med., *59*, 1945, 52.)

Antigenic structure: IX, XII: g, m, t: —.

Source: From a severe case of gastroenteritis in man.

Habitat: Not reported from other sources as yet.

74. **Salmonella sp.** (Type Claiborne). (*Salmonella claibornei* Wilcox and Lennox, Jour. Immunol., *49*, 1944, 71.)

Antigenic structure: I, IX, XII: k: 1, 5. . . .

Source: Culture isolated from human feces at Camp Claiborne, Louisiana.

Habitat: Not known from other sources as yet.

75. **Salmonella sp.** (Type Sendai). (K type, Shimojo, quoted from Kauffmann, Die Bakteriologie der Salmonella-Gruppe, Kopenhagen, 1941, 265; Atypical Paratyphosus A, Aoki and Sakai, Cent. f. Bakt., I Abt., Orig., *95*, 1925, 152; Sendai type, White, Med. Res. Council, Spec. Rept. Ser. No. 103, 1926, 118; *Salmonella sendaiensis* Haupt, Ergebnisse der Hyg., *13*, 1932, 673; *Salmonella sendai* Schütze et al., Jour. Hyg., *34*, 1934, 345; *Eberthella sp.* (Sendai Type) F. Smith, in Manual, 5th ed., 1939, 464.)

Antigenic structure: [I], IX, XII: a: 1, 5. . . .

Source: Isolated in 1922 by K. Shimojo in Japan from a case of paratyphoid. Later isolated by Aoki and Sakoi from feces, urine and blood of typhoid patients.

Habitat: A natural pathogen of man causing enteric fever.

76. **Salmonella sp.** (Type Miami). (*Salmonella miami* Edwards and Moran, Jour. Bact., *50*, 1945, 259.)

Antigenic structure: IX, XII: a: 1, 5. . . .

Differ culturally and biochemically from organisms of Sendai Type (Edwards and Moran, Jour. Bact., *50*, 1945, 257).

Source: Twenty-four cultures isolated by Mrs. Mildred Galton in Florida. Fourteen cultures were from cases of acute gastroenteritis, one from a patient with chronic diarrhoea, 4 from food handlers, 4 from chimpanzees thought to be affected with bacillary dysentery and one from pickles which caused an outbreak of food poisoning. One culture was from Borman, Wheeler, West and Mickle (Amer. Jour. Pub. Health, *33*, 1943, 127) and was isolated from a case of gastroenteritis in Connecticut. Another culture was from Seligmann, Saphra and Wassermann (Amer. Jour. Hyg., *38*, 1943, 225) and was isolated from a case of enteric fever.

Habitat: Apparently widely distributed as a natural pathogen of man and apes.

77. **Salmonella sp.** (Type Durban). (*Salmonella durban* Henning, Rhodes and Gordon-Johnstone, Onderstepoort Jour. Vet. Sci. An. Ind., *16*, 1941, 103; also see Kauffmann, Acta Path. et Microbiol. Scand., *19*, 1942, 523.)

Antigenic structure: IX, XII: a: e, n, z_{15}. . . .

Source: Isolated by Dr. J. Gordon-Johnstone in Durban, So. Africa from feces of a woman affected with gastroenteritis.

Habitat: Not reported from other sources as yet.

78. **Salmonella sp.** (Type Onarimon). (*Salmonella onarimon* Kisida, Kitasato Arch. of Exper. Med., *17*, 1940, 1.)

Antigenic formula: I, IX, XII: b: 1, 2. . . .

Source: From the feces of a paratyphoid B carrier. Later found in other cases of enteric fever resembling typhoid.

Habitat: Cause of a typhoid-like disease in man.

79. **Salmonella sp.** (Type Eastbourne). (*Salmonella eastbourne* Leslie and Shera, Jour. Path. and Bact., *34*, 1931, 533.)

Antigenic structure: [I], IX, XII: e, h: 1, 5. . . .

May or may not produce indole (Kauffmann, Die Bakteriologie der Salmonella-Gruppe, 1941, 12.)

Source: From human enteric fever at Eastbourne, England.

Habitat: A natural pathogen for man. Also found in turkeys.

80. **Salmonella sp.** (Type Panama). (Jordan, Amer. Jour. Trop. Med., *14*, 1934, 27; *Salmonella panama* Kauffmann, Cent. f. Bakt., I Abt., Orig., *132*, 1934, 160.)

Antigenic structure: I, IX, XII: l, v: 1, 5. . . .

Source: From human food poisoning at Fort Amador, in Panama, Canal Zone. Also isolated in New York City, Germany and Uruguay. Also in reptiles, hogs and chickens (Edwards and Bruner, Jour. Inf. Dis., *72*, 1943, 64).

Habitat: Apparently widely distributed.

81. **Salmonella sp.** (Type Dar es Salaam). (Brown, Duncan and Henry, Lancet, *1*, 1926, 117; Dar-es-Salaam Typus, Schütze, Arch. f. Hyg., *100*, 1928, 192; *Salmonella daressalaamensis* Haupt, Ergebnisse der Hyg., *13*, 1932, 673; *Salmonella dar-es-salaam* Schütze et al., Jour. Hyg., *34*, 1934, 346.)

Antigenic structure: I, IX, XII: l, w: e, n. . . .

Liquefies gelatin (Jordan, Jour. Inf. Dis., *58*, 1936, 126).

Source: Isolated by Butler in 1922 from a case of pyrexia at Dar es Salaam, East Africa. Cultures have also been reported from Zanzibar.

Habitat: Known thus far from human sources only.

82. **Salmonella sp.** (Type Goettingen). (*Salmonella goettingen* Hohn, Cent. f. Bakt., I Abt., Orig., *146*, 1940, 218.)

Antigenic structure: IX, XII: l, v: e, n, z_{15}. . . .

The complete formula was developed by Kauffmann (Acta Path. et Microbiol. Scand., *17*, 1940, 429.)

Source: Not given. Presumably from a human source.

Habitat: Not reported.

83. **Salmonella sp.** (Type Java). (*Salmonella javiana* Alley and Pijoan, Yale Jour. Biol. and Med., *15*, 1942, 229; Edwards and Bruner, Jour. Immunol., *44*, 1942, 319.)

Antigenic structure: [I], IX, XII: l, z_{28}: 1, 5. . . .

Source: From Eijkman Institute in Java. Isolated from feces of a child. Subsequently two cultures labeled N112 and N140, isolated in Panama from human carriers, were received from Col. Chas. G. Sinclair.

Habitat: Reported as yet from human sources only.

84. **Salmonella gallinarum** (Klein) Bergey et al. (*Bacillus gallinarum* Klein, Cent. f. Bakt., *5*, 1889, 689; Pheasant bacillus, Klein, Jour. Path. & Bact., *2*, 1893, 214; *Bacillus phasiani septicus* Kruse, in Flügge, Die Mikroorganismen, 3 Aufl., *2*, 1896, 410; *Bacterium sanguinarium* Moore, 12th and 13th Ann. Rpt. for 1895–96, U. S. Dept. Agr. Bur. An. Ind., 1897, 188; see Moore, U. S. Dept. Agr. Bur. An. Ind., Bull. 8, 1895, 63; *Bacillus phasiani* Migula, Syst. der Bakt., *2*, 1900, 769; *Bacterium phasiani septicus* Chester, Ann. Rept. Del. Col. Agr. Exp. Sta., *9*, 1897, 74; *Bacterium gallinarum* Chester, *ibid.*, 80; *Bacterium pyogenes sanguinarium* Berry and Ernst, Jour. Med. Res., *10* (N. S. *5*), 1903–04, 402; *Bacillus pseudo-cholerae gallinarum* Trincas, Giorn. della R. Soc. Ital. d'Igiene, 1908, 385; *Bacillus typhi gallinarum alcalifaciens* and *Bacillus typhi gallinarum* Pfeiler and Rehse, Mitt. K. Inst. f. Landw. Bromberg, *5*, 1913, 306; *Eberthella sanguinaria* Bergey et al., Manual, 1st ed., 1923, 231; Bergey et al., Manual, 2nd ed., 1925, 236; *Shigella gallinarum* Weldin, Iowa State Coll. Jour. Sci., *1*, 1927, 179.) From Latin, of chickens.

Bacterium jeffersonii Hadley, Elkins and Caldwell, Rhode Island Agr. Exp. Sta. Bull. 174, 1918, 169 (*Eberthella jeffersonii* Bergey et al., Manual, 1st ed., 1923, 230; *Shigella jeffersonii* Bergey et al., Manual, 4th ed., 1934, 394). *Shigella jeffersonii* is identical serologically with *Salmonella gallinarum* (St. John-Brooks and Rhodes, Jour. Path. and Bact., *26*, 1923, 433).

Rods: 0.4 to 0.6 by 0.8 to 1.6 microns, with rounded ends, occurring singly or (in blood) in short chains. Non-motile. Gram-negative.

Gelatin colonies: Small, grayish-white, finely granular, circular, entire.

Gelatin stab: Slight, grayish-white surface growth with slight grayish, filiform growth in stab. No liquefaction.

Agar colonies: Moist, grayish, circular, entire.

Agar slant: Thin, gray streak, with irregular margin, moist, glistening.

Broth: Turbid with heavy, flocculent sediment.

Litmus milk: Reaction unchanged, becoming translucent. No coagulation.

Potato: Slight grayish growth.

Indole not formed.

Nitrites produced from nitrates.

Acid but no gas from glucose, fructose, galactose, mannose, xylose, arabinose, maltose, dextrin, mannitol, dulcitol and isodulcitol. Lactose, sucrose, glycerol, salicin and sorbitol are not attacked.

Reduces trimethylamine oxide (Wood and Baird, *loc. cit.*).

Hydrogen sulfide is sometimes formed.

Aerobic, facultative.

Optimum temperature 37°C.

Antigenic structure: [I], IX, XII: —: —. Identical with *Salmonella pullorum*,

and related to *Salmonella typhosa*. [I] antigen noted by Kauffmann (Acta Path. et Microbiol. Scand., Suppl. 54, 1944, 36).

Source and habitat: The causative agent of fowl typhoid (clearly to be distinguished from fowl cholera), and identical with Moore's infectious leukemia of fowls. Infectious for rabbits and all poultry, canaries and certain wild birds (quail, grouse, pheasant) by feeding or by injection. Found once in a normal human carrier.

85. **Salmonella pullorum** (Rettger) Bergey et al. (*Bacterium pullorum* Rettger, Jour. Med. Res., *21* (N.S. *16*), 1909, 117; also see Rettger, N. Y. Med. Jour., *71*, 1900, 803; *ibid.*, *73*, 1901, 267; Rettger and Harvey, Jour. Med. Res., *18* (N.S. *13*), 1908, 277; *Bacillus pullorum* Smith and Ten Broeck, Jour. Med. Res., *31* (N. S. *26*), 1915, 547; Bergey et al., Manual, 1st ed., 1923, 218; Typus pullorum, Kauffmann, Zentbl. f. d. ges. Hyg., *25*, 1931, 273.) From Latin, of chickens.

Rods: 0.3 to 0.5 by 1.0 to 2.5 microns, occurring singly. Non-motile. Gram-negative.

Gelatin colonies: Grayish-white, moist, lobate, with grape-leaf surface.

Gelatin stab: Slight, grayish surface growth. No liquefaction.

Agar colonies: Grayish-white, smooth, glistening, entire to undulate.

Agar slant: Develops as discrete, translucent colonies.

Broth: Turbid.

Litmus milk: Acid, becoming alkaline. No coagulation.

Potato: Slow development, grayish.

Indole not formed.

Nitrites produced from nitrates.

Acid and gas from glucose, fructose, galactose, mannose, arabinose, xylose, mannitol and rhamnose. Does not attack lactose, sucrose, maltose, dextrin, salicin, raffinose, sorbitol, adonitol, dulcitol or inositol. Gas may be slight or absent (cf. *Salmonella gallinarum*). Xylose may be fermented late (see Weldin, Iowa State Coll. Jour. Sci., *1*, 1927, 165). Maltose fermenting strains may occur (Hinshaw, Browne and Taylor, Jour. Inf. Dis., *73*, 1943, 197).

Reduces trimethylamine oxide (Wood and Baird, *loc. cit.*).

Hydrogen sulfide is formed.

Aerobic, facultative.

Optimum temperature 37°C.

Antigenic structure, IX, XII: —: The complete antigenic formula of *S. pullorum* is IX, XII_1, XII_2, XII_3, while that of *S. gallinarum* seems to be IX, XII_1, XII_3. Antigen XII_2 is variable in *S. pullorum* (Edwards and Bruner, Cornell Vet., *36*, 1946, 318) and $XII_2{}^{++}$ and $XII_2{}^{+}$ forms occur. The $XII_2{}^{++}$ forms are synonymous with the X strains of Younie (Can. Jour. Comp. Med., *5*, 1941, 164).

Source: Isolated from chickens and other birds, as well as calves, hogs, rabbits and man. Occasionally produces food poisoning or gastroenteritis in man (Mitchell, Garlock and Broh-Kahn, Jour. Inf. Dis., *79*, 1946, 57).

Habitat: The cause of white diarrhoea in young chicks. Infects the ovaries and eggs of adult birds.

85a. *Salmonella gallinarum* var. *Duisburg*. (Müller, Münch. med. Wchnschr., *80*, 1933, 1771; Kauffmann, Cent. f. Bakt., I Abt., Orig., *132*, 1934, 337.)

Antigenically identical with *Salmonella gallinarum* and *Salmonella pullorum*. Differs from *Salmonella gallinarum* in its slow fermentation of maltose, failure to ferment d-tartrate and in not forming H_2S.

Source and habitat: Isolated from acute gastroenteritis in man.

86. **Salmonella sp.** (Type Canastel). (*Salmonella canastel* Randall and Bruner, Jour. Bact., *49*, 1945, 511.) Source of name not given.

Liquefies gelatin.

Antigenic structure: IX, XII: z_{29}: 1, 5. . . .

Source: Isolated in North Africa from American soldiers acting as food handlers.

Habitat: Not reported from other sources as yet.

87. **Salmonella sp.** (Type Italia). (*Salmonella italiana* Bruner and Edwards, Proc. Soc. Exp. Biol. and Med., *58*, 1945, 289.)

Antigenic structure: IX, XII: l, v: 1, 11. . . .

Source: Two cultures, one isolated from a case of bloody diarrhoea and the other from a case of gastroenteritis in man. Found in Italy by Lt. Col. Robert Hebble and by Capt. Ira C. Evans.

Habitat: Not reported from other sources as yet.

88. **Salmonella sp.** (Type Napoli). (*Salmonella napoli* Bruner and Edwards, Proc. Soc. Exper. Biol. and Med., *58*, 1945, 289.)

Antigenic structure: [I], IX, XII: l, z_{13}: e, n, x. . . .

Source: Ten cultures isolated from normal feces and from cases of gastroenteritis in Naples, Italy. The first culture was isolated by Capt. W. H. Ewing.

Habitat: Not reported from other sources as yet.

89. **Salmonella sp.** (Type Loma Linda). (*Salmonella loma linda* Edwards, Proc. Soc. Exper. Biol. and Med., *57*, 1944, 104.)

Antigenic structure: IX, XII: a: e, n, x. . . .

Source: Single culture isolated by Dr. T. F. Judefind, Loma Linda, California from the spinal fluid of a baby that died of meningitis.

Habitat: Not reported from other sources as yet.

90. **Salmonella sp.** (Type New York). (*Salmonella new york* Kauffmann, Acta Path. et Microbiol. Scand., Suppl. 54, 1944, 35.)

Antigenic structure: IX, XII: l, v: 1, 5. . . .

Source: Found by Dr. F. Schiff, New York in a study of a culture received under the label *S. panama* Strain No. 431. Regarded at the present time as a strain of *Salmonella javiana* by Dr. Kauffman (personal communication, March, 1947).

Habitat: Not reported from other sources as yet.

91. **Salmonella sp.** (Type London). (*Salmonella* Type L, White, Med. Res. Council Spec. Rept. Ser. 103, 1926, 37; *Salmonella londonensis* Haupt, Ergebnisse der Hyg., *13*, 1932, 675; *Salmonella london* Schütze et al., Jour. Hyg., *34*, 1934, 346.)

Antigenic structure: III, X, XXVI: l, v: 1, 6. . . .

Source: Isolated in London from the feces of a gastroenteritis patient from Reading, England.

Habitat: Found in human infections, in hogs and in chickens.

92. **Salmonella sp.** (Type Give). (*Salmonella give* Kauffmann, Ztschr. f. Hyg., *120*, 1937, 177.)

Antigenic structure: III, X, XXVI: l, v; l, 7. . . .

Source: From feces of a patient with pernicious anemia. Also found in the U. S. A. and Germany. Occurs in fowls and hogs (Edwards and Bruner, Jour. Inf. Dis., *72*, 1943, 64).

Habitat: Apparently widely distributed.

93. **Salmonella sp.** (Type Uganda). (*Salmonella uganda* Kauffmann, Acta Path. et Microbiol. Scand., *17*, 1940, 189.)

Antigenic structure: III, X, XXVI: l, z_{13}: 1, 5. . . .

Source: Isolated in Uganda by Dr. H. G. Wiltshire from a human spleen on autopsy. Typed by Dr. F. Kauffmann.

Habitat: Not reported from other sources as yet.

94. **Salmonella anatis** (Rettger and Scoville) Bergey et al. (*Bacterium anatis* Rettger and Scoville, Abst. Bact., *3*, 1910, 8; not *Bacterium anatis* Migula, Syst. d. Bakt., *2*, 1900, 364; *Bacterium anatum* Rettger and Scoville, Jour. Inf. Dis., *26*, 1920, 217; *Escherichia anata* Bergey et al., Manual, 1st ed., 1923, 198; Bergey et al., Manual, 2nd ed., 1925, 238; *Salmonella anatum* Bergey et al., Manual, 3rd ed., 1930, 344.) From Latin, of the duck.

With the transfer of this organism to the genus *Salmonella*, the original species name *anatis* again becomes available in spite of the earlier use of this species name by Migula for Cornil and Toupet's Bacillus der Enten-cholera (Compt. rend. Acad. Sci., Paris, *106*, 1888, 1737). The latter organism is stated by Rettger and Scoville (1920, *loc. cit.*, 220) to be indistinguishable from *Pasteurella avi-septica*.

Morphology and cultural characters like those of *Salmonella enteritidis*.

Kauffmann (Ztschr. f. Hyg., *119*, 1937, 352) describes a lactose-splitting variant of this species.

Antigenic structure: III, X, XXVI: e, h: 1, 6. . . .

Reduces trimethylamine oxide (Wood and Baird (*loc. cit.*).

Source: Isolated from an epizootic of keel in ducklings. Also found in intestinal infections in chickens and man. Frequently occurs in association with *Salmonella typhimurium*.

Habitat: Widely distributed in man and domestic animals.

95. **Salmonella sp.** (Type Muenster). (*Salmonella anatum* var. *muenster*, Kauffmann and Silberstein, Cent. f. Bakt., I Abt., Orig., *132*, 1934, 431; *Salmonella muenster* Kauffmann, Ztschr. f. Hyg., *140*, 1937, 177.)

Antigenic structure: III, X, XXVI: e, h: 1, 5. . . .

Source: Isolated by Dr. Besserer in Muenster from food poisoning. Also isolated in Uruguay from human sources.

Habitat: Not known from any but human sources as yet.

96. **Salmonella sp.** (Type Nyborg). (*Salmonella anatum* var. *nyborg*, Kristensen and Bojlén, Cent. f. Bakt., I Abt., Orig., *136*, 1936, 294; *Salmonella nyborg* Kauffmann, Ztschr. f. Hyg., *120*, 1937, 189.)

Antigenic structure: III, X, XXVI: e, h: 1, 7. . . .

Source: From a case of acute enteritis in a young girl in Nyborg, Denmark.

Habitat: Known only from human sources as yet.

97. **Salmonella sp.** (Type Vejle). (*Salmonella vejle* Harhoff, quoted from Kauffmann, Die Bakteriologie der Salmonella-Gruppe, Kopenhagen, 1941, 274.)

Antigenic structure: III, X, XXVI: e, h: 1, 2, 3. . . .

Source: Isolated by E. Møller, Copenhagen, from a case of acute gastroenteritis.

Habitat: Not reported from other sources as yet.

98. **Salmonella sp.** (Type Meleagris). (*Salmonella meleagridis* Bruner and Edwards, Amer. Jour. Hyg., *34*, 1941, 82; not *Salmonella meleagridis* Rettger, Plastridge and Cameron, Jour. Inf. Dis., *53*, 1933, 279.)

Antigenic structure: III, X, XXVI: e, h: l, w. . . .

Source: Original cultures isolated by Dr. B. S. Pomeroy, Univ. of Minnesota, from two distinct outbreaks of infection in turkey poults. Stated to be the same as *Salmonella bantam* from Batavia, Java (Kauffmann, Acta Path. et Microbiol. Scand., *19*, 1942, 529).

Habitat: In addition to the two strains isolated in Minnesota (Bruner and Edwards, Kentucky Agr. Exp. Sta., Bull. 434, 1942), the same type was recognized among cultures received from Massachusetts, Michigan, Pennsylvania, Maryland, South America and Japan. Also isolated from German soldiers in

Norway by Tesdal (Kauffmann, Die Bakteriologie der Salmonella-Gruppe, 1941, 295) and from snakes by Hinshaw and McNeil (Amer. Jour. Vet. Res., *6*, 1945, 264).

99. **Salmonella sp.** (Type Shangani). (*Salmonella shangani* Kauffmann, Acta Path. et Microbiol. Scand., *16*, 1939, 347.)

Antigenic structure: III, X, XXVI: d: 1, 5. . . .

Source: Isolated in Zanzibar by Dr. J. D. Robertson from a woman with enteric fever.

Habitat: Known only from human sources as yet.

100. **Salmonella sp.** (Type Zanzibar). (*Salmonella zanzibar* Kauffmann, Acta Path. et Microbiol. Scand., *16*, 1939, 347.)

Antigenic structure: III, X, XXVI: k: 1, 5. . . .

Source: Isolated in Zanzibar by Dr. J. D. Robertson from a typhoid carrier.

Habitat: Also found in chickens (Edwards).

101. **Salmonella sp.** (Type Amager). (*Salmonella amager* Kauffmann, Acta Path. et Microbiol. Scand., *16*, 1939, 347.)

Antigenic structure: III, X, XXVI: y: 1, 2, 3. . . .

Source: Isolated in Copenhagen from the feces of a person suffering from gastroenteritis.

Habitat: Known only from human sources as yet.

102. **Salmonella sp.** (Type Lexington). (*Salmonella lexington* Rubin, Jour. Bact., *40*, 1940, 463; Edwards, Bruner and Rubin, Proc. Soc. Exper. Biol. and Med., *44*, 1940, 395.)

Antigenic structure: III, X, XXVI: z_{10}: 1, 5. . . .

According to Kauffmann (Die Bakteriologie der Salmonella-Gruppe, 1941, 276), Dr. Erber of Java has found a *Salmonella* type with the same antigenic structure and has given it the name *Salmonella batavia*.

Source: Isolated from mesenteric lymph glands of apparently normal hogs by Dr. H. L. Rubin, Univ. of Kentucky, Lexington, Ky.

Habitat: Also reported from turkeys.

103. **Salmonella sp.** (Type Weltevreden). (*Salmonella weltevreden* Mertens, quoted from Kauffmann, Acta Path. et Microbiol. Scand., *19*, 1942, 529.)

Antigenic structure: III, X, XXVI: r: z_6. . . .

Source: Isolated by Dr. W. K. Mertens, Batavia, Java, according to Kauffmann (*loc. cit.*).

Habitat: Not recorded in available literature.

104. **Salmonella sp.** (Type Orion). (*Salmonella* type, var. *orion* and *Salmonella orion* Barnes, Cherry and Myers, Jour. Bact. *50*, 1945, 578.) From a seaman on the S. S. Orion.

Antigenic structure: III, X, XXVI: y: 1, 5. . . .

Source: From rectal swab specimen from a normal food handler.

Habitat: Not reported from other sources as yet.

105. **Salmonella sp.** (Type Butantan). (*Salmonella butantan* Peluffo, Bier, Amaral, and Biocca, Mem. Inst. Butantan, *19*, 1946, 211.)

Antigenic structure: III, X, XXVI: b: 1, 5. . . .

Source: Isolated by Dr. C. A. Peluffo from a case of diarrhoea in a child.

Habitat: Not reported from other sources as yet.

106. **Salmonella sp.** (Type Newington). (Anatum C_1 No. 3071, N.C.T.C., London, Kauffmann and Silberstein, Cent. f. Bakt., I Abt., Orig., *132*, 1934, 434; *Salmonella newington* Edwards, Jour. Hyg., *37*, 1937, 384.)

Antigenic structure: III, XV: e, h: 1, 6. . . .

Source: Isolated from ducks from Newington, Connecticut by Dr. L. F.

Rettger. Also found in hogs, silver foxes and man. Kauffmann (Ztschr. f. Hyg., *120*, 1937, 177) has described a related type (*Salmonella tim*) from a case of enteritis in Tim, Denmark.

Habitat: Widely distributed.

107. **Salmonella sp.** (Type Selandia). (*Salmonella selandia* Kauffmann, Ztschr. f. Hyg., *120*, 1937, 189.)

Antigenic structure: III, XV: e, h: 1, 7. . . .

Source: Isolated from the feces of a sailor on the S. S. Selandia after a voyage to Asia and Australia. Was patient in Bispebjerg Hospital with pleuropneumonia at the time.

Habitat: Known only from human sources as yet.

108. **Salmonella sp.** (Type New Brunswick). (*Salmonella new brunswick* Edwards, Jour. Hyg., *37*, 1937, 384; also see Kauffmann, Ztschr. f. Hyg., *120*, 1937, 189.)

Antigenic structure: III, XV: l, v: 1, 7. . . .

Source: Isolated by Dr. F. R. Beaudette, New Brunswick, New Jersey from a chicken. Also isolated from gastroenteritis in man.

Habitat: Apparently widely distributed.

109. **Salmonella sp.** (Type Illinois). (*Salmonella illinois* Edwards and Bruner, Proc. Soc. Exper. Biol. and Med., *48*, 1941, 240.)

Antigenic structure: (III), (XV), XXXIV: z_{10}: 1, 5. . . .

Source: Isolated from hogs in Illinois by Dr. Robert Graham, from Hungarian partridges in Michigan by Miss Virginia Stoney and from turkeys in Minnesota by Dr. B. S. Pomeroy.

Habitat: Also reported from hogs and man (Edwards).

110. **Salmonella sp.** (Type Senftenberg). (Typus Senftenberg, Kauffmann, Ztschr. f. Hyg., *111*, 1930, 221; *Salmonella senftenberg* Schütze et al., Jour. Hyg., *34*, 1934, 339; *Salmonella senftenbergensis* Haupt, Ergebnisse der Hyg., *13*, 1932, 673.)

Antigenic structure: I, III, XIX: g, s, t: —.

Source: From a case of acute gastroenteritis in a boy in Senftenberg, Denmark. Cultures have frequently been found from persons and also from young turkeys.

Habitat: Apparently widely distributed.

111. **Salmonella sp.** (Type Niloese). (*Salmonella niloese* Kauffmann, Acta path. et Microbiol. Scand., *16*, 1939, 347.)

Antigenic structure: I, III, XIX: d: z_6. . . .

Source: Isolated in Copenhagen from a case of acute gastroenteritis in Niloese, Denmark. Later found frequently in gastroenteritis in Denmark.

Habitat: Known only from human sources as yet.

112. **Salmonella sp.** (Type Simsbury). (*Salmonella simsbury* Bruner and Edwards, Proc. Soc. Exper. Biol. and Med., *50*, 1942, 174.)

Antigenic structure: I, III, XIX: z_{27}: —.

Source: Original culture isolated by Dr. E. K. Borman, State Dept. Health Lab., Hartford, Conn., from a normal human carrier from Simsbury, Conn. Edwards states (1946) that this may be a variant of *Salmonella sp.* (Type Senftenberg).

Habitat: Also found in turkeys (Bruner and Edwards, Kentucky Agr. Exp. Sta., Bull. 434, 1942, 9).

113. **Salmonella sp.** (Type Taksony). (*Salmonella taksony* Rauss, Ztschr. f. Immunitätsforsch., *103*, 1943, 220.)

Antigenic structure: I, III, XIX: i: z_6. . . .

Source: Isolated from a healthy carrier (Hungary).

Habitat: Not reported from other sources as yet.

114. **Salmonella sp.** (Type Kentucky). (*Salmonella kentucky* Edwards, Jour. Hyg., *38*, 1938, 306.)

Antigenic structure: (VIII), XX: i: z_6. . . .

Source: Isolated from the intestinal tract of a chick affected with coccidiosis and ulcerative enteritis. Found at Lexington, Kentucky.

Habitat: Also reported from many species of fowls, from hogs and from man (Edwards).

115. **Salmonella sp.** (Type Aberdeen). (*Salmonella aberdeen* J. Smith, Jour. Hyg., *34*, 1934, 357.)

Antigenic structure: XI: i: 1, 2, 3. . . .

Source: Isolated in Aberdeen, Scotland, from the stool of a child suffering from acute enteritis. Also isolated by Timmerman in Utrecht from Ovomaltine, and by Edwards in Kentucky from birds. See Kauffmann, Die Bakteriologie der Salmonella-Gruppe, Kopenhagen, 1941, 279.

Habitat: Apparently widely distributed.

116. **Salmonella sp.** (Type Rubislaw). (*Salmonella rubislaw* Smith and Kauffmann, Jour. Hyg., *40*, 1940, 122.)

Antigenic structure: IX: r: e, n, x. . . .

Source: Isolated in Aberdeen, Scotland from the feces of a child suffering from enteritis. Also found by Tesdal in Oslo, Norway. Reported by Hinshaw and McNeil from snakes (Amer. Jour. Vet. Res., *6*, 1945, 264).

Habitat: Apparently widely distributed.

117. **Salmonella sp.** (Type Pretoria). (*Salmonella pretoria* Henning, Rhodes and Gordon-Johnstone, Onderstepoort Jour. Vet. Sci. An. Ind., *16*, 1941, 103.)

Antigenic structure: XI: k: 1, 2, 3. . . .

Source: Isolated by Dr. M. W. Henning in Pretoria, South Africa from an infection in garbage-fed hogs.

Habitat: Not reported from other sources as yet.

118. **Salmonella sp.** (Type Venezia). (*Salmonella veneziana* Bruner and Joyce, Jour. Bact., *50*, 1945, 371.)

Antigenic structure: XI: i: e, n, x. . . .

Source: Culture received from Capt. J. K. Hill. Isolated from an apparently normal Italian civilian food handler in Venice, Italy.

Habitat: Not known from other sources as yet.

119. **Salmonella sp.** (Type Solt). (*Salmonella solt* Rauss, Ztschr. f. Immunitätsforsch., *103*, 1943, 220.)

Antigenic structure: XI: y: 1, 5. . . .

Source: Isolated from a healthy carrier (Hungary).

Habitat: Not reported from other sources as yet.

120. **Salmonella sp.** (Type St. Lucie). (*Salmonella luciana* Moran, Edwards and Bruner, Proc. Soc. Exp. Biol. and Med., *64*, 1947, 89.) From St. Lucie, Florida.

Antigenic structure: XI: a: e, n, z_{15}. . . .

Source: Single culture isolated by Mrs. Mildred Galton from feces of a normal human carrier.

Habitat: Not known from other sources as yet.

121. **Salmonella sp.** (Type Senegal). (*Salmonella senegal* Hinshaw and McNeil, Jour. Bact., *52*, 1946, 349.)

Antigenic structure: XI: r: 1, 5. . . .

Source: Isolated by Dr. W. L. Hinshaw from a green mamba snake.

Habitat: Not known from other sources as yet.

122. **Salmonella sp.** (Type Marseille). (*Salmonella marseille* Moran, Edwards and Bruner, Proc. Soc. Exp. Biol. and Med., *64*, 1947, 89.)

Antigenic structure: XI: a: 1, 5. . . .

Source: Isolated in Marseilles, France by Capt. Wm. Sutton from feces.

Habitat: Not known from other sources as yet.

123. **Salmonella sp.** (Type Grumpy). (*Salmonella grumpensis* Hormaeche and Peluffo, quoted from Hormaeche et al., Jour. Bact., *47*, 1944, 323.) Named for a person called grumpy.

Antigenic structure: XIII, XXIII, XXXVI: d: 1, 7 . . . as given by Kauffmann (Acta Path. et Microbiol. Scand., Suppl. 54, 1944, 37).

Source: Isolated in Uruguay from a guinea pig. Also studied by Kauffmann (*loc. cit.*).

Habitat: Not reported from other sources as yet.

124. **Salmonella sp.** (Type Poona). (*Salmonella poona* Bridges and Scott, Jour. Roy. Army Med. Corps, *55*, 1935, 221.)

Antigenic structure: XIII, XXII: z: 1, 6. . . .

Source: Isolated by Dr. L. Dunbar in Poona from the stool of a child suffering from enteritis.

Habitat: Also reported from hogs (Edwards).

125. **Salmonella sp.** (Type Borbeck). (*Salmonella borbeck* Hohn and Herrimann, Cent. f. Bakt., I Abt., Orig., *145*, 1940, 219.)

Antigenic structure: XIII, XXII: l, v: 1, 6. . . .

Source: Isolated from the feces of a child with typhoid. Found in the Borbeck section of Essen, Germany.

Habitat: Not reported from other sources as yet.

126. **Salmonella sp.** (Type Mississippi). (*Salmonella mississippi* Edwards, Cherry and Bruner, Proc. Soc. Exp. Biol. and Med., *54*, 1943, 263.)

Antigenic structure: I, XIII, XXIII, b: 1, 5. . . .

Source: Isolated by the State Dept. of Health of Mississippi from the stool of a normal food handler.

Habitat: Also reported from hogs (Edwards).

127. **Salmonella sp.** (Type Wichita). (*Salmonella wichita* Schiff and Strauss, Jour. Inf. Dis., *65*, 1939, 125.)

Antigenic structure: I, XIII, XXIII: d: —.

Source: Isolated by Miss B. McKinlay in an epidemic of enteritis affecting babies, Wichita, Kansas. Also in fowls, turkeys and hogs (Edwards and Bruner, Jour. Inf. Dis., *72*, 1942, 64).

Habitat: Apparently widely distributed.

128. **Salmonella sp.** (Type Havana). (*Salmonella havana* Schiff and Saphra, Jour. Inf. Dis., *68*, 1941, 125.)

Antigenic structure: I, XIII, XXIII: f, g: —.

Source: Isolated during an outbreak of 21 cases of meningitis in children in a maternity hospital in Havana, Cuba.

Habitat: Not reported from other sources as yet.

129. **Salmonella sp.** (Type Worthington). (*Salmonella worthington* Edwards and Bruner, Jour. Hyg., *38*, 1938, 716.)

Antigenic structure: I, XIII, XXIII: l, w: z. . . .

Source: Isolated by Dr. B. S. Pomeroy from a turkey poult from Worthington, Minnesota. Also found in a hen. Later additional cultures were found in other birds, in rodents, cattle, hogs and man. (Edwards and Bruner, Jour. Inf. Dis., *72*, 1943, 64).

Habitat: Apparently widely distributed.

130. **Salmonella sp.** (Type Cuba). (*Salmonella cubana* Seligmann, Wasserman and Saphra, Jour. Bact., *51*, 1946, 123.)

Antigenic structure: I, XIII, XXIII: z_{29}: —.

Source: Isolated in Havana, Cuba by Dr. Arturo Curbelo from diseased baby chicks.

Habitat: Not reported from other sources as yet.

131. **Salmonella sp.** (Type Heves). (*Salmonella heves* Rauss, Ztschr. f. Immunitätsforsch., *103*, 1943, 220.)

Antigenic structure: VI, XIV, XXIV: d: 1, 5. . . .

Source: Isolated from a healthy carrier (Hungary).

Habitat: Not reported from other sources as yet.

132. **Salmonella sp.** (Type Carrau). (*Salmonella carrau* Hormaeche, Peluffo and Salsamendi, Arch. Urug. de Med., Cirug. y Espec., *12*, 1938, 377; Hormaeche, Peluffo and Pereyra, Jour. Bact., *47*, 1944, 323.)

Antigenic structure: VI, XIV, XXIV: y: 1, 7. . . .

Source: Isolated in Uruguay from mesenteric glands of normal hogs.

Habitat: Also reported from feces and blood in man, once from flies and one culture from human blood from Mexico.

133. **Salmonella sp.** (Type Onderstepoort). (*Salmonella onderstepoort* Henning, Jour. Hyg., *36*, 1936, 525.)

Antigenic structure: (I), VI, XIV, XXV: e, (h): 1, 5. . . .

Source: Isolated in So. Africa by Dr. J. H. Mason from sheep in Onderstepoort. Also isolated from man by Dr. Hormaeche (Uruguay) and from turkeys (Edwards, Kentucky).

Habitat: Apparently widely distributed in warm-blooded animals.

134. **Salmonella sp.** (Type Florida). (*Salmonella florida* Cherry, Edwards and Bruner, Proc. Soc. Exp. Biol. and Med., *52*, 1943, 125; Galton and Quan, Amer. Jour. Hyg., *38*, 1943, 173.)

Antigenic structure: (I), VI, XIV, XXV: d: 1, 7. . . .

Source: Isolated by Mrs. Mildred Galton from feces of a patient with a febrile disease and diarrhoea.

Habitat: Also reported from reptiles (Edwards).

135. **Salmonella sp.** (Type Madelia). (*Salmonella madelia* Cherry, Edwards and Bruner, Proc. Soc. Exp. Biol. and Med., *52*, 1943, 125.)

Antigenic structure: (I), VI, XIV, XXV: y: 1, 7. . . .

Source: A single culture isolated by Dr. B. S. Pomeroy from the liver of a poult that died of septicemia. Found in Madelia, Minnesota.

Habitat: Also reported from man (Edwards).

136. **Salmonella sp.** (Type Sundsvall). (*Salmonella sundsvall* Olin and Alin, Acta Path. et Microbiol. Scand., *20*, 1943, 607.)

Antigenic structure: (I), VI, XIV, XXV: z: e, n, x. . . .

Source: Isolated from a person suffering from gastroenteritis.

Habitat: Not reported from other sources as yet.

137. **Salmonella sp.** (Type Orient). (*Salmonella orientalis* Carlquist and Conte, Bull. U. S. Army Med. Dept., *6*, 1946, 343.)

Antigenic structure: XVI: k: e, n, z_{15}. . . .

Source: Isolated from U. S. Army personnel who had been prisoners of the Japanese Army in the Orient.

Habitat: Not known from other sources as yet.

138. **Salmonella sp.** (Type Hvittingfoss). (*Salmonella hvittingfoss* Tesdal, Ztschr. f. Hyg., *118*, 1936, 533.)

Antigenic structure: XVI: b: e, n, x. . . .

Source: Isolated during a food poisoning outbreak in Hvittingfoss, a small town in Norway. Caused by eating

pultoste, a kind of soft cheese. Cultures secured from the cheese, from the persons who were poisoned, from sewage and from a foal.

Habitat: Evidently rather widely distributed.

139. **Salmonella sp.** (Type Gaminara). (*Salmonella gaminara* Hormaeche, Peluffo and Salsamendi, Arch. Urug. de Med., Cirug. y Espec., *12*, 1938, 377; *ibid.*, *14*, 1939, 217.) Named in honor of Prof. Gaminara of Uruguay.

Antigenic structure: XVI: d: 1, 7. . . .

Source: Isolated from the feces of a child suffering from enteritis.

Habitat: Not known from other sources as yet.

140. **Salmonella sp.** (Type Szentes). (*Salmonella szentes* Rauss, Ztschr. f. Immunitätsforsch., *103*, 1943, 220.)

Antigenic structure: XVI: k: 1, 2, 3. . . .

Source: Isolated by Dr. K. Rauss from a healthy carrier (Hungary).

Habitat: Not reported from other sources as yet.

141. **Salmonella sp.** (Type Kirkee). (*Salmonella kirkee* Bridges and Dunbar, Jour. Roy. Army Med. Corps, *67*, 1936, 289.)

Antigenic structure: XVII: b: 1, 2. . . .

Source: Isolated in Kirkee, India from the feces of a child suffering from acute enteritis. The source of the infection was thought to be a dog.

Habitat: Not reported from other sources as yet.

142. **Salmonella sp.** (Type Cerro). (*Bacterium cerro* Hormaeche, Peluffo and Salsamendi, Arch. Urug. Med., Cirug. y Espec., *12*, 1938, 377; *Salmonella cerro* Hormaeche, Peluffo and Aleppo, *ibid.*, *19*, 1941, 125.)

Antigenic structure: XVIII: z_4, z_{23}, z_{25}: —.

Source: Isolated from the mesenteric glands of normal hogs from Cerro, Uruguay.

Habitat: Also isolated by the authors in 13 cases of infantile infections. Found also in chickens (Edwards).

143. **Salmonella sp.** (Type Minnesota). (*Salmonella minnesota* Edwards and Bruner, Jour. Hyg., *38*, 1938, 716.)

Antigenic structure: XXI, XXVI: b: e, n, x. . . .

Source: Isolated in Minnesota by Dr. B. S. Pomeroy from a young turkey.

Habitat: Also reported from cattle and man.

144. **Salmonella sp.** (Type Tel Aviv). (*Salmonella tel-aviv* Kauffmann, Acta Path. et Microbiol. Scand., *17*, 1940, 1.)

Antigenic structure: XXVIII: y: e, n, z_{15}. . . .

Source: Isolated in Tel Aviv, Palestine by Dr. G. B. Simmins during an epizootic affecting young chickens during which 50 per cent died.

Habitat: Not known from other sources as yet.

145. **Salmonella sp.** (Type Pomona). (*Salmonella pomona* Edwards, Proc. Soc. Exp. Biol. and Med., *58*, 1945, 291.)

Antigenic structure: XXVIII: y: 1, 7. . . .

Source: Single culture isolated from the intestine of a poult in 1941 by Dr. W. R. Hinshaw.

Habitat: Also reported from man (Edwards).

146. **Salmonella sp.** (Type Ballerup). (*Salmonella ballerup* Kauffmann and Møller, Jour. Hyg., *40*, 1940, 246.)

Antigenic structure: XXIX, [Vi]: z_{14}: —.

Source: From the feces of a woman from the town of Ballerup, Denmark. A cause of gastroenteritis.

Habitat: Not known from other sources as yet.

147. **Salmonella sp.** (Type Hormaeche). (*Salmonella hormaechei* Monteverde, Nature, *154*, 1944, 676.) Named in honor of Dr. Hormaeche of Uruguay.

Antigenic structure: XXIX, [Vi]*: z_{30}, [z_{31}]: —.

Source: From the ovary of a hen whose blood gave a positive reaction with the *S. pullorum* antigen. Found in Buenos Aires by Dr. Monteverde.

Habitat: Also reported from hogs and man (Edwards).

*Reported by Dr. P. R. Edwards (personal communication).

148. **Salmonella sp.** (Type Urbana). (*Salmonella urbana* Edwards and Bruner, Jour. Inf. Dis., *69*, 1941, 223.)

Antigenic structure: XXX: b: e, n, x. . . .

Source: One culture was received from Dr. Robert Graham, Urbana, Illinois and was isolated from the contents of the colon of a hog affected with hemorrhagic enteritis. The second culture was isolated from the intestinal tract of a chicken by Dr. W. L. Mallmann, East Lansing, Michigan.

Habitat: Also reported from man (Edwards).

149. **Salmonella sp.** (Type Adelaide). (*Salmonella adelaide* Cleland, Med. Jour. Australia, *31*, 1944, 59.)

Antigenic structure: XXXV: f, g: —.

Source: Isolated in Adelaide, Australia by Miss Nancy Atkinson from two fatal cases resembling typhoid fever.

Habitat: Not reported from other sources as yet.

150. **Salmonella sp.** (Type Inverness). (*Salmonella inverness* Edwards and Hughes, Proc. Soc. Exp. Biol. and Med., *56*, 1944, 33.)

Antigenic structure: XXXVIII: k: 1, 6. . . .

Source: Isolated by Mrs. Mildred Galton and Mr. M. S. Quan of the Florida State Department of Health, from the stool of a normal food handler, Inverness, Florida.

Habitat: Not reported from other sources as yet.

151. **Salmonella sp.** (Type Champaign). (*Salmonella champaign* Edwards, Proc. Soc. Exp. Biol. and Med., *58*, 1945, 291.)

Antigenic structure: XXXIX: k: 1, 5. . . .

Source: Single culture isolated from the liver of an adult hen by Dr. Robert Graham, Champaign, Illinois.

Habitat: Not reported from other sources as yet.

Appendix I: The following species and varieties are largely taken from Hauduroy, Ehringer, Urbain, Guillot and Magrou, Dictionnaire des Bactéries Pathogènes, Paris, 1937, 446–472. The relationships of many of these are not clear.

Bacillus canariensis Migula. (Bacillus der Kanarienvögelseptikämie, Rieck, Deutsche Ztschr. f. Thiermed., *15*, 1889, 69; Migula, Syst. d. Bakt., *2*, 1900, 770; *Bacillus avisepticus* Chester, Man. Determ. Bact., 1901, 220; not *Bacillus avisepticus* Kitt, in Kolle and Wassermann, Handb. d. path. Mikroorg., 1 Aufl., *2*, 1903, 544.) Associated with intestinal catarrh and liver changes in canaries. Hadley, Elkins and Caldwell (Rhode Island Agr. Exp. Sta., Bull. 174, 1918, 178) regard this as probably *Bacillus gallinarum* Klein.

Bacillus friedebergensis Kruse. (Bacillus der Friedeberger Fleischvergiftung, Gaffky and Paak, Mitt. a. d. kaiserl. Gesundheitsamte, *6*, 1890, 159; Kruse, in Flügge, Die Mikroorganismen, 3 Aufl., *2*, 1896, 378; *Bacterium friedebergensis* Chester, Ann. Rept. Del. Col. Agr. Exp. Sta., *9*, 1897, 73.) From sausage in meat poisoning.

Salmonella abortus canis Gard. (Ztschr. f. Hyg., *121*, 1938, 139.) From the feces of four persons with paratyphoid apparently spread from an infected dog. Kauffmann regards this as identical with *Salmonella schottmuelleri*.

Salmonella annamensis Hauduroy et al. (Un bacille du groupe des *Salmonella*, Normet, Urbain and Chaillot, Compt. rend. Soc. Biol., Paris, *101*, 1929, 752; Hauduroy et al., Dict. d. Bact. Path.,

1937, 450.) Isolated during an epidemic of dysentery at Hué (Annam) in 1925.

Salmonella archibaldii Castellani and Chalmers. (Man. Trop. Med., 3rd ed., 1919, 940.)

Salmonella carolina (Castellani) Castellani and Chalmers. (*Bacillus carolinus* Castellani, Ann. di Med. Nav. e Colon., *1*, 1918; Castellani and Chalmers, Man. Trop. Med., 3rd ed., 1919, 940.)

Salmonella coagulans (Castellani) Hauduroy et al. (*Bacillus coagulans* Castellani, 1916; *Balkanella coagulans* Castellani, 1916; see Castellani and Chalmers, Man. Trop. Med., 3rd ed., 1919, 935; Hauduroy et al., Dict. d. Bact. Path., 1937, 453.)

Salmonella columbensis (Castellani) Castellani and Chalmers. (*Bacterium columbense* Castellani, Proc. Meeting Ceylon Branch British Assoc., 1905, quoted from Castellani, Cent. f. Bakt., I Abt., Orig., *74*, 1914, 197; *Bacillus columbensis* Castellani, Jour. Trop. Med. and Hyg., *20*, 1917, 181; Castellani and Chalmers, Ann. Inst. Past., *34*, 1920, 609; *Morganella columbensis* Fulton, Jour. Bact., *46*, 1943, 81.) The cause of columbensis fever. Isolated from feces, urine and blood.

Salmonella enteritidis var. v, Hauduroy et al. (Bacille para-Gärtner V, Rochaix and Couture, Revue de Microbiologie appliquée, *2*, 1936; Hauduroy et al., Dict. d. Bact. Path., 1937, 454.) Found associated with *Salmonella enteritidis* in meat pies and in the feces of individuals with food poisoning.

Salmonella enteritidis-yellow, a variety of *Salmonella enteritidis* Deskowitz and Buchbinder (Jour. Bact., *29*, 1935, 293). Cultures differ from typical *Salmonella enteritidis* in producing a yellow, water-soluble pigment. From the feces of a rat with enteric infection.

Salmonella foetida Bergey et al. (*Coccobacillus foetidus ozenae* Perez, Ann. Inst. Past., *13*, 1899, 937; *Coccobacillus (foetidus) ozaenae* Ward, Jour. Bact., *2*, 1917, 619; Bergey et al., Manual, 1st ed., 1923, 220; *Bacterium foetida* Weldin and Levine, Abst. Bact., *7*, 1923, 13; *Escherichia foetida* Bergey et al., Manual, 2nd ed., 1925, 222.) From chronic rhinitis, ozena. See Manual, 4th ed., 1934, 380 for a description of this species.

Salmonella holsatiensis Roelcke. (Also *Salmonella* Typ Holstein, Roelcke, Cent. f. Bakt., I Abt., Orig., *137*, 1936, 464.) According to Kauffmann (Ztschr. f. Hyg., *119*, 1937, 352) the O-antigens of this rapid fermenter of salicin and weak indole-former are identical with those of *Salmonella poona*. The H-antigens have not been compared as yet.

Salmonella icteroides (Sanarelli) Bergey et al. (Bacillo icteroide, Sanarelli, Il Policlinico, *4*, 1897, 412; *Bacillus icteroides* Sanarelli, British Med. Jour., July 3, 1897, 7; *Bacterium icteroides* Lehmann and Neumann, Bakt. Diag., 2 Aufl., *2*, 1899, 241; Bergey et al., Manual, 1st ed., 1923, 218.) From yellow fever cadavers. See Manual, 5th ed., 1939, 604 for a description of this species.

Salmonella iwo-jima Lindberg and Bayliss. (Jour. Inf. Dis., *79*, 1946, 92.) Isolated from a soldier on Iwo-Jima during a routine examination of food handlers. Belongs to Group C. Antigenic structure: VI, VIII: i: 1, 5 . . . Described too recently to be included in the main body of the text.

Salmonella liceagi Leon. (Rev. Inst. Salubridad y Enferm. Trop., *3*, 1942, 273.) From feces. This probably belongs in the coliform group.

Salmonella macfadyeanii (Weldin and Levine) Weldin. (*Bacterium macfadyeanii* Weldin and Levine, Abst. Bact., *7*, 1923, 13; Weldin, Iowa State Jour. Sci., *1*, 1927, 168.) Associated with hog cholera.

Salmonella mexicana Varela and Olarte. (Rev. Inst. Salubridad y Enferm. Trop., *4*, 1943, 313.) From feces.

Salmonella monshaui Carlquist and Coates. (Jour. Bact., *53*, 1947, 249.) Isolated from stump of a soldier who suffered traumatic amputation of a leg in the fighting around Monshau, Ger-

many. Belongs to Group F. Antigenic structure: XXXV: m. t.:—Described too recently to be included in the main body of the text.

Salmonella nocardi Pacheco. (Compt. rend. Soc. Biol., Paris, *106*, 1931, 372 and 1018.) Pathogenic for parrots and pigeons.

Salmonella oahu Lindberg and Bayliss. (Jour. Inf. Dis., *79*, 1946, 92.) Isolated from a case of gastroenteritis in a soldier hospitalized on Oahu. Belongs to Group B. Antigenic structure: IV, V, XII: 1, v: 1, 2, 3 . . . Described too recently to be included in the main body of the text.

Salmonella ostrei (Besson and Ehringer) Hauduroy et al. (*Bacillus ostrei* Besson and Ehringer, Compt. rend. Soc. Biol., Paris, *87*, 1922, 1017; Hauduroy et al., Dict. d. Bact. Path., 1937, 460.) Isolated from oysters. Not pathogenic for laboratory animals.

Salmonella para-asiatica (Castellani) Hauduroy et al. (*Bacillus paraasiaticus* Castellani, 1916; see Castellani and Chalmers, Man. Trop. Med., 3rd ed., 1919, 950; Hauduroy et al., Dict. d. Bact. Path., 1937, 461.)

Salmonella para-coagulans (Castellani) Hauduroy et al. (*Bacillus para-coagulans* Castellani, 1914; see Castellani and Chalmers, Man. Trop. Med., 3rd ed., 1919, 950; Hauduroy et al., Dict. d. Bact. Path., 1937, 461.)

Salmonella pauloensis Gomes. (Rev. Inst. Adolfo Lutz, *2*, 1942, 231.) May be the same as *Salmonella columbensis*.

Salmonella pseudo-asiatica (Castellani) Castellani and Chalmers. (*Bacillus pseudo-asiaticus* Castellani, Cent. f. Bakt., I Abt., Orig., *65*, 1912, 266; Castellani and Chalmers, Man. Trop. Med., 3rd ed., 1919, 940.)

Salmonella pseudo-asiatica var. *mobilis* Hauduroy et al. (*Bacillus pseudo-asiaticus mobilis* Castellani, see Castellani and Chalmers, Man. Trop. Med., 3rd ed., 1919, 952; Hauduroy et al., Dict. d. Bact. Path., 1937, 463.)

Salmonella (?) *pseudo-carolina* (Castellani) Hauduroy et al. (*Bacillus pseudocarolinus* Castellani, 1917; see Castellani and Chalmers, Man. Trop. Med., 3rd ed., 1919, 952; Hauduroy et al., Dict. d. Bact. Path., 1937, 463.)

Salmonella (?) *pseudo-columbensis* (Castellani) Hauduroy et al. (*Bacillus pseudo-columbensis* Castellani, see Castellani and Chalmers, Man. Trop. Med., 3rd ed., 1919, 954; Hauduroy et al., Dict. d. Bact. Path., 1937, 464.)

Salmonella pseudo-morganii (Castellani) Hauduroy et al. (*Bacillus pseudomorgani* Castellani, see Castellani and Chalmers, Man. Trop. Med., 3rd ed., 1919, 954; Hauduroy et al., Dict. d. Bact. Path., 1937, 464.)

Salmonella ranicida Hauduroy et al. (Bacille pathogène isolé des grenouilles, Gheorghiu and Balmus, Compt. rend. Soc. Biol., Paris, *108*, 1931, 1002; Hauduroy et al., Dict. d. Bact. Path., 1937, 466.) Pathogenic for frogs.

Salmonella saipan Lindberg and Bayliss. (Jour. Inf. Dis., *79*, 1946, 92.) Isolated from a case of gastroenteritis in a soldier hospitalized on Saipan. Belongs to Group E. Antigenic structure: III, X, XXVI: z_6. . . . Described too recently to be included in the main body of the text.

Salmonella schottmülleri var. *alvei* Hauduroy et al. (*Bacillus paratyphi alvei* Bahr, Skand. Veterin. Tidsk., *9*, 1919; Hauduroy et al., Dict. d. Bact. Path., 1937, 469.) Pathogenic for bees and wasps.

Salmonella veboda (Castellani) Castellani and Chalmers. (*Bacillus veboda* Castellani, Jour. Trop. Med. and Hyg., *20*, 1917, 181; Castellani and Chalmers, Man. Trop. Med., 3rd ed., 1919, 939; *Bacterium veboda* Weldin and Levine, Abst. Bact., *7*, 1923, 13.)

Salmonella watareka (Castellani) Bergey et al. (*Bacillus watareka* Castellani, Rept. Advisory Committee for Trop. Dis. Research Fund for 1912, London, 1913; *Bacterium watareka* Weldin and Levine, Abst. Bact., *7*, 1923, 13; Bergey et al., Manual, 1st ed., 1923, 219.)

Salmonella werahensis (Castellani) Hauduroy et al. (*Bacillus werahensis* Castellani, see Castellani and Chalmers, Man. Trop. Med., 3rd ed., 1919, 956; Hauduroy et al., Dict. d. Bact. Path., 1937, 471.)

Salmonella wesenbergoides (Castellani) Hauduroy et al. (*Bacillus wesenbergoides* Castellani, 1916; see Castellani and Chalmers, Man. Trop. Med., 3rd ed., 1919, 935; Hauduroy et al., Dict. d. Bact. Path., 1937, 471.)

Salmonella willegoda (Castellani) Castellani and Chalmers. (*Bacillus willegoda* Castellani; Castellani and Chalmers, Man. Trop. Med., 3rd ed., 1919, 939.)

Salmonella woliniae (Castellani) Castellani and Chalmers. (*Bacillus woliniae* Castellani, Jour. Trop. Med. and Hyg., *20*, 1917, 181; Castellani and Chalmers, Man. Trop. Med., 3rd ed., 1919, 939; *Bacterium woliniae* Weldin and Levine, Abst. Bact., *7*, 1923, 13.)

Appendix II: The following species have been thought to belong to the genus *Eberthella*, i.e., do not produce gas from glucose. Descriptions of nearly all of the species listed in the genus *Eberthella* will be found in the Manual, 5th ed., 1939, 464–469.

Bacillus subentericus Ford. (Studies from the Royal Victoria Hosp., Montreal, *1*, 1903, 40; also see Jour. Med. Res., *1*, 1901, 218.) From feces.

Bacterium typhi flavum Dresel and Stickl. (Deutsche med. Wchnschr., *54*, 1928, 517.) From feces of persons with typhoid fever. Cruickshank (Jour. Hyg., *35*, 1935, 354) reports that a variety of yellow chromogenic saprophytes have been identified as belonging to this species, none of which could be regarded as yellow variants of *Salmonella typhosa* (Zopf) White. They apparently belong in the genus *Flavobacterium* Bergey et al.

Eberthella alcalifaciens de Salles Gomes. (Rivista do Inst. Adolfo Lutz, *4*, 1944, 191.) From catarrhal feces of an infant.

Eberthella belfastiensis (Weldin and Levine) Bergey et al. (*Bacterium coli anaerogenes* Lembke, Arch. f. Hyg., *26*, 1896, 299; *Bacterium lembkei* Migula, Syst. d. Bakt., *2*, 1900, 417; *Bacterium anaerogenes* Chester, Man. Determ. Bact., 1901, 135; *Bacillus belfastiensis II*, Wilson, Jour. Hyg., *8*, 1908, 543; *Bacillus anaerogenes* Holland, Jour. Bact., *5*, 1920, 217; *Bacterium belfastiensis* Weldin and Levine, Abst. Bact., *7*, 1923, 13; Bergey et al., Manual, 1st ed., 1923, 226; *Bacillus coli anaerogenes* Kerrin, Jour. Hyg., *28*, 1928, 4; *Escherichia anaerogenes* Bergey et al., Manual, 3rd ed., 1930, 321; *Castellanus colianaerogenes* Castellani, Cent. f. Bakt., I Abt., Orig., *125*, 1932, 42.) From feces.

Eberthella bentotensis (Castellani and Chalmers) Bergey et al. (*Bacillus bentotensis* Castellani, Cent. f. Bakt., I Abt., Orig., *65*, 1912, 262; *Bacterium bentotensis* Weldin and Levine, Abst. Bact., *7*, 1923, 15; Bergey et al., Manual, 1st ed., 1923, 227; *Castellanus bentotensis* Castellani, Cent. f. Bakt., I Abt., Orig., *125*, 1932, 42.) From the intestinal canal.

Eberthella chylogena (Ford) Bergey et al. (*Bacillus chylogenes* Ford, Studies from the Royal Victoria Hospital, Montreal, *1*, No. 5, 1903, 62; Bergey et al., Manual, 1st ed., 1923, 224.) From the intestinal canal.

Eberthella dubia (Chester) Bergey et al. (Meiner Bakterie, Bleisch, Ztschr. f. Hyg., *13*, 1893, 31; *Bacillus dubius* Kruse, in Flügge, Die Mikroorganismen, 3 Aufl., *2*, 1896, 323; *Bacillus bleischii* Kruse, *ibid.*, 704; *Bacterium dubius* Chester, Ann. Rept. Del. Col. Agr. Exp. Sta., *9*, 1897, 93; Bergey et al., Manual, 1st ed., 1923, 225.) From the intestinal canal.

Eberthella enterica (Ford) Bergey et al. (*Bacillus entericus* Ford, Studies from the Royal Victoria Hospital, Montreal, *1*, No. 5, 1903, 40; also see Jour. Med. Research, *1*, 1901, 211; not *Bacillus*

entericus Castellani, 1907 (*Enteroides entericus* Castellani and Chalmers, Man. Trop. Med., 3rd ed., 1919, 941); Bergey et al., Manual, 1st ed., 1923, 223.) From the intestinal canal.

Eberthella insecticola Steinhaus. (Jour. Bact., *42*, 1941, 762 and 769.) From the intestinal tracts of grasshoppers, milkweed bugs and stinkbugs.

Eberthella kandiensis (Castellani) Bergey et al. (*Bacillus kandiensis* Castellani, Cent. f. Bakt., I Abt., Orig., *65*, 1912, 262; *Eberthus kandiensis* Castellani and Chalmers, Man. Trop. Med., 3rd ed., 1919, 936; *Bacterium kandiensis* Weldin and Levine, Abst. Bact., *7*, 1923, 13; Bergey et al., Manual, 1st ed., 1923, 225.) From feces.

Eberthella lewisii Weldin. (Organism $B3_2$, Lewis, Local Gov. Board Rept. Med. Suppl. London, 1910–11, Appen. B, No. 2, 1911, 314; *Bacterium lewisii* Weldin and Levine, Bact. Abst., *7*, 1923, 13; Weldin, Iowa State Col. Jour. Sci., *1*, 1926, 172.) From feces of a normal child.

Eberthella oedematiens Assis. (Boletin do Inst. Vital, Brazil, *5*, 1928.) From the intestinal canal.

Eberthella oxyphila (Ford) Bergey et al. (*Bacterium oxyphilum* Ford, Studies from the Royal Victoria Hospital, Montreal, *1*, No. 5, 1903, 49; Bergey et al., Manual, 1st ed., 1923, 224.) From the intestinal canal.

Eberthella pauloensis Mello. (Jornal dos Clinicos, Rio de Janeiro, No. 18–30, Sept., 1937, 7 pp.) From feces of a dysentery patient.

Eberthella priztnitzi (Castellani and Chalmers) Hauduroy et al. (*Bacillus priztnitzi* Castellani, Jour. Trop. Med. and Hyg., *20*, 1917, 182; *Eberthus priztnitzi* Castellani and Chalmers, Man. Trop. Med., 3rd ed., 1919, 936; *Bacterium priztnitzi* Weldin and Levine, Abst. Bact., *7*, 1923, 13; Hauduroy et al., Dict. d. Bact. Path., 1937, 186.) From cases of paraenteric fever.

Eberthella proteosimilis Wassilien. (Cent. f. Bakt., I Abt., Orig., *151*, 1944, 423.) Colonies show motility on agar. From feces of a dysentery patient.

Eberthella pyogenes (Migula) Bergey et al. (*Bacillus pyogenes foetidus* Passet, Fortschr. der Med., 1885; *Bacillus foetidus* Trevisan, I generi e le specie delle Batteriacee, 1889, 16; *Bacterium pyogenes foetidus* Chester, Ann. Rept. Del. Col. Agr. Exp. Sta., *9*, 1897, 141; *Bacterium pyogenes* Migula, Syst. der Bakt., *2*, 1900, 381; *Lankoides pyogenes* Castellani and Chalmers, Man. Trop. Med., 3rd ed., 1919, 938; *Bacillus pyogenes-foetidus* Holland, Jour. Bact., *5*, 1920, 220; Bergey et al., Manual, 1st ed., 1923, 226; *Castellanus pyogenes* Castellani, Cent. f. Bakt., I Abt., Orig., *125*, 1932, 42.) From a rectal abscess.

Eberthella talavensis (Castellani) Bergey et al. (*Bacillus talavensis* Castellani, Cent. f. Bakt., I Abt., Orig., *65*, 1912, 262; *Eberthus talavensis* Castellani and Chalmers, Man. Trop. Med., 3rd ed., 1919, 936; *Bacterium talavensis* Weldin and Levine, Abst. Bact., *7*, 1923, 13; Bergey et al., Manual, 1st ed., 1923, 225.) From the intestinal canal.

Eberthella tarda Assis. (Boletin do Inst. Vital, Brazil, *5*, 1928.) From the intestinal canal.

Eberthella wesenbergi (Castellani and Chalmers) Hauduroy et al. (*Bacillus wesenberg* Castellani, 1913; *Wesenbergus wesenbergi* Castellani and Chalmers, Man. Trop. Med., 3rd ed., 1919, 940; Hauduroy et al., Dict. d. Bact. Path., 1937, 191.)

Eberthella wilsonii Weldin. (*Bacillus belfastiensis V*, Wilson, Jour. Hyg., *8*, 1908, 543; Weldin, Iowa State Col. Jour. Sci., *1*, 1926, 174.) From feces.

Eberthella xenopa Schrire. (Trans. Royal Soc. So. Africa, *17*, 1928, 43.) From wound infection in frogs.

Wesenbergus fermentosus Castellani and Chalmers. (Man. Trop. Med., 3rd ed., 1919, 940.) From blood. Isolated by Archibald in the Anglo-Egyptian Sudan.

Genus II. **Shigella** *Castellani and Chalmers.**

(Castellani and Chalmers, Man. Trop. Med., 3rd ed., 1919, 936; subgenera, *Flexnerella* and *Shigella*, Castellani and Chalmers, *ibid.*, 938; *Castellanus* Carruti, Jour. Trop. Med. and Hyg., July 15, 1930; *Proshigella* Borman, Stuart and Wheeler, Jour. Bact., *48*, 1944, 363.) Named for Prof. I. Shiga, the Japanese bacteriologist who discovered the dysentery bacillus in 1898.

Non-motile rods, although cultures of some of the less well-known species have been reported as motile. Produce acid but no gas from carbohydrates except with some types of *Shigella paradysenteriae*. Do not liquefy gelatin. Some species produce acid from lactose and form indole. Some species reduce trimethylamine oxide to trimethylamine, others do not.† Some species will grow at 45.5°C (Eijkman test).‡ Pathogenic (causing dysenteries) or non-pathogenic species, all living in the bodies of warm-blooded animals. Carried by polluted water supplies and by flies.

The type species is *Shigella dysenteriae* (Shiga) Castellani and Chalmers.

Key to the species of genus **Shigella.****

I. No acid from mannitol.
  A. No acid from lactose. Milk not coagulated.
    1. Indole not produced.
      a. Acid but no gas from glucose.
        1. *Shigella dysenteriae.*
      aa. Acid and a small amount of gas from glucose.
        4a. See *Shigella paradysenteriae* (Type Newcastle).
    2. Indole produced.
        2. *Shigella ambigua.*
  B. Acid formed slowly from lactose.
    1. Indole not produced.
        3. *Shigella gintottensis.*

II. Acid from mannitol (one type produces a small amount of gas).
  A. No acid from lactose.
    1. No acid from rhamnose, xylose or dulcitol.
        4. *Shigella paradysenteriae.*
    2. Acid from rhamnose, xylose and dulcitol.
        5. *Shigella alkalescens.*
    3. Acid from xylose but not from dulcitol.
        6. *Shigella pfaffii.*
  B. Acid formed slowly from lactose.
    1. Indole not produced.
      a. Acid from rhamnose. None from xylose.
        7. *Shigella sonnei.*
      aa. No acid from rhamnose. Acid from xylose.
        8. *Shigella equirulis.*

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* Completely revised by Dr. Frederick Smith, McGill University, Montreal, P. Q., Canada, December, 1938; further revision, April, 1946.

† Wood, Baird and Keeping, Jour. Bact., *46*, 1943, 106.

‡ Stuart and Rustigian, Jour. Bact., *46*, 1943, 105.

** See Weil, Jour. Immunology, *55*, 1947, 363–405.

2. Indole produced.
   a. Acid from dulcitol.
      9. *Shigella ceylonensis.*
   aa. No acid from dulcitol.
      10. *Shigella madampensis.*

III. Action on mannitol unknown.
   A. No acid from lactose.
      1. Indole is produced.
         11. *Shigella septicemiae.*

1. **Shigella dysenteriae** (Shiga) Castellani and Chalmers. (Bacillus of Japanese dysentery, Shiga, Cent. f. Bakt., I Abt., *23*, 1898, 599; *Bacillus dysenteriae* Shiga, Cent. f. Bakt., I Abt., *24*, 1898, 817; *Bacillus japanicus* Migula, Syst. d. Bakt., *2*, 1900, 755; *Bacillus shigae* Chester, Man. Determ. Bact., 1901, 228; *Bacillus dysentericus* Ruffer and Willmore, Brit. Med. Jour., *2*, 1909, 862; *Bacterium dysenteriae* Lehmann and Neumann, Bakt. Diag., 5 Aufl., *2*, 1912, 348; not *Bacterium dysenteriae* Chester, Man. Determ. Bact., 1901, 145; Castellani and Chalmers, Man. Trop. Med., 3rd ed., 1919, 935; *Bacterium shigae* Holland, Jour. Bact., *5*, 1920, 220; *Eberthella dysenteriae* Bergey et al., Manual, 2nd ed., 1925, 250.) Latinized, of dysentery.

Rods: 0.4 to 0.6 by 1.0 to 3.0 microns, occurring singly. Non-motile. Gram-negative.

Gelatin colonies: Small, grayish, smooth, homogeneous, entire to slightly undulate.

Gelatin stab: Grayish surface growth. No liquefaction.

Agar slant: Grayish, filiform to echinulate, smooth, entire to undulate growth.

Broth: Slightly turbid, with grayish sediment.

Litmus milk: Slightly acid, then alkaline.

Potato: Delicate, grayish to slightly brownish streak.

Indole not produced.

Nitrites produced from nitrates.

Acid but no gas from glucose, fructose, raffinose, glycerol and adonitol. Does not attack arabinose, xylose, maltose, lactose, sucrose, salicin, mannitol, dulcitol or rhamnose.

Does not reduce trimethylamine oxide (Wood et al., Jour. Bact., *46*, 1943, 106).

Aerobic, facultative.

Optimum temperature 37°C. Does not grow at 45.5°C (Eijkman's reaction, Stuart et al., Jour. Bact., *46*, 1943, 105).

Serologically homogeneous and different from the other species of *Shigella*. Forms a potent exotoxin.

Source: From widespread epidemics of dysentery in Japan.

Habitat: A cause of dysentery in man and monkeys.

2. **Shigella ambigua** (Andrewes) Weldin. (Bazillus Schmitz, Schmitz, Ztschr. f. Hyg., *84*, 1917, 449; *Bacillus ambiguus* Andrewes, The Lancet, *194*, 1918, 560; *Bacillus dysenteriae* "Schmitz", Murray, Jour. Roy. Army Med. Corps, *31*, 1918, 257; *Bacterium ambiguum* Levine, Abst. Bact., *4*, 1920, 15; not *Bacterium ambiguum* Chester, Del. Col. Agr. Exp. Sta. Ann. Rept., *11*, 1900, 59; *Eberthella ambigua* Bergey et al., Manual, 1st ed., 1923, 229; *Bacillus paradysenteriae X*, Stutzer, Cent. f. Bakt., I Abt., Orig., *90*, 1923, 12; *Bacterium schmitzii* Weldin and Levine, Abst. Bact., *7*, 1923, 13; Weldin, Iowa State College Jour. Sci., *1*, 1927, 177; *Shigella schmitzii* Hauduroy et al., Dict. d. Bact. Path., 1937, 496.) From Latin, uncertain.

Morphology and colony characters indistinguishable from those of *Shigella dysenteriae*.

Acid from glucose and rhamnose.

Does not attack xylose, maltose, lactose, sucrose, dextrin, glycerol, mannitol or dulcitol.

Indole is produced.

Does not reduce trimethylamine oxide (Wood et al., Jour. Bact., *46*, 1943, 106).

Aerobic, facultative.

Optimum temperature 37°C. Does not grow at 45.5°C (Stuart et al., Jour. Bact., *46*, 1943, 105).

Serologically homogeneous and different from the other species of *Shigella*. Does not form an exotoxin.

Source: Found in feces in a dysentery epidemic in a prison in Germany.

Habitat: A cause of human dysentery.

3. **Shigella gintottensis** (Castellani) Hauduroy et al. (*Bacillus gintottensis* Castellani, 1910; see Castellani and Chalmers, Man. Trop. Med., 3rd ed., 1919, 948; *Lankoides gintottensis* Castellani and Chalmers, *ibid.*, 938; *Castellanus gintottensis* Castellani, 1930; Castellani, Jour. Trop. Med. and Hyg., *36*, 1933, 109; Hauduroy et al., Dict. d. Bact. Path., 1937, 488.)

Rods: Non-motile. Gram-negative.

Morphology and cultural characters indistinguishable from those of *Shigella dysenteriae*.

Litmus milk: Acid and coagulation; decolorized.

Indole not formed.

Acid, but no gas, from lactose, glucose, arabinose and galactose. No acid from sucrose, dulcitol, mannitol, maltose, dextrin, raffinose, adonitol, inulin, sorbitol, levulose, inositol, salicin and glycerol.

Antigenic structure not known.

Source: From feces in cases of dysentery.

Habitat: A cause of human dysentery.

4. **Shigella paradysenteriae** (Collins) Weldin. (*Bacillus dysenteriae* Flexner, Phil. Med. Jour., *6*, 1900, 414; *Bacillus dysenteriae* Hiss and Russell, Medical News, *82*, 1903, 289; *Bacillus dysenteriae* Strong, Jour. Amer. Med. Assoc., *35*, 1906, 498; *Bacillus paradysenteriae* Collins, Jour. Inf. Dis., *2*, 1905, 620; includes weakly toxic strains of dysentery bacilli, Groups I and II, Sonne, Cent. f. Bakt., I Abt., Orig., *75*, 1915, 408; *Shigella flexneri* Castellani and Chalmers, Man. Trop. Med., 3rd ed., 1919, 937; *Shigella dysenteriae* (Hiss and Russell, and Strong types) Castellani and Chalmers, *ibid.*, 937; not *Shigella paradysenteriae* Castellani and Chalmers, *ibid.*, *937*; *Bacillus flexneri* Levine, Jour. Inf. Dis., *27*, 1920, 31; *Bacterium flexneri* Levine, Abst. Bact., *4*, 1920, 15; *Bacterium dysenteriae* (Flexner type) and *Bacterium paradysenteriae* Holland, Jour. Bact., *5*, 1920, 215; *Eberthella flexneri* Weldin and Levine, Abst. Bact., *7*, 1923, 13; *Eberthella paradysenteriae* Bergey et al., Manual, 1st ed., 1923, 230; Weldin, Iowa State College Jour. Sci., *1*, 1927, 178.) Latinized, like dysentery.

Rods: 0.5 by 1.0 to 1.5 microns. Non-motile. Gram-negative.

Morphologically these organisms are like *Shigella dysenteriae*.

Culturally these organisms differ from *Shigella dysenteriae* in that they ferment mannitol. No acid is produced from lactose, rhamnose, xylose or dulcitol.

Does not reduce trimethylamine oxide (Wood et al., Jour. Bact., *46*, 1943, 106).

Does not form a potent exotoxin.

Aerobic, facultative.

Optimum temperature 37°C. Does not grow at 45.5°C (Stuart et al., Jour. Bact., *46*, 1943, 105).

Antigenically the organisms of this species are not homogeneous.

Boyd (Trans. Roy. Soc. Trop. Med. and Hyg., *33*, 1940, 553) has shown that the mannitol-fermenting *Shigella* include many organisms previously unknown or unclassified because they did not agree with the classical types of Andrewes and Inman (Med. Res. Council, Special Rept. Ser. No. 42, London, 1919). With these, on grounds of antigenic structure, will be included the gas-forming Manchester bacillus of Downie, Wade and Young (Jour. Hyg., *33*, 1933, 196) and

both mannitol-fermenting and non-fermenting Newcastle bacilli (Clayton and Warren, Jour. Hyg., *28*, 1929, 355 and *29*, 1929, 191).

The following tables are taken from Boyd (*loc. cit.*).

TABLE 1.—Classification of *Shigella paradysenteriae*.

New Name	Old Name
Bacillus dysenteriae Flexner I	Andrewes and Inman V (Flexner)
Bacillus dysenteriae Flexner II	Andrewes and Inman W (Strong)
Bacillus dysenteriae Flexner III	Andrewes and Inman Z
Bacillus dysenteriae Flexner IV	Type 103
Bacillus dysenteriae Flexner V	Type P 119
Bacillus dysenteriae Flexner VI	88-Newcastle-Manchester group
Bacillus dysenteriae Boyd I	Type 170
Bacillus dysenteriae Boyd II	Type P 288
Bacillus dysenteriae Boyd III	Type D1

The six Flexner types possess a common group antigen and separate type-specific antigens. The three Boyd types are distinct antigenically from each other and from the Flexner types.

Two new Flexner types (Type 953 = provisional Type VII and Type 1296/7 = provisional Type VIII) have been described by Francis (Jour. Path. and Bact., *58*, 1946, 320) as this section goes to press. Also see Boyd (*ibid.*, 297).

TABLE 2.—Subclassification of *Bacillus dysenteriae* Flexner VI (including the Newcastle bacillus).

	Lactose	Glucose	Mannitol	Dulcitol	Sucrose	Indole
Type 88 (33 per cent of strains)	—	A	A	—	—	—
Type 88 (66 per cent of strains)	—	A	A	(late) A	—	—
Manchester bacillus..........	—	AG	AG	(late) AG		—
Newcastle bacillus............	—	AG	—	(late) AG		—

Source: From feces in cases of dysentery.

Habitat: A cause of dysentery in man. A cause of summer diarrhoea in children.

NOTE: The term *Bacillus paradysenteriae* is used by Kruse (Münch. med. Wchnschr., 1917, 1309) for the *Escherichia coli*-like motile and gas-forming Gram-negative rods that have been found to cause dysentery-like diseases. Kruse (Deut. med. Wchnschr., *27*, 1901, 388) uses the term pseudodysentery for the group that includes the Flexner, Strong, and Hiss and Russell types. See Lehmann and Neumann, Bakt. Diag., 7 Aufl., *2*, 1927, 456. Gardner (Med. Res. Council, System of Bacteriology, *4*, 1929, 170) states that "Kruse's terms *B. dysenteriae* for Shiga, and *Bacillus pseudodysenteriae* for the Flexner-Sonne-Schmitz groups have, however, never taken root outside the German-speaking world".

4a. *Shigella paradysenteriae* (Type Newcastle). (Clayton and Warren, Jour. Hyg., *28*, 1929, 355 and *29*, 1929, 191; *Bacillus dysenteriae* Flexner VI in part, Boyd, Trans. Roy. Soc. Trop. Med. and Hyg., *33*, 1940, 553.)

Rods: Non-motile. Gram-negative.

In peptone water solution, lactose, mannitol, and sucrose not fermented. Glucose, maltose and dulcitol fermented.

Peculiarities of the organism are: (1) Occasionally a slight bubble of gas is produced from glucose and dulcitol, (2) when the substrate is dissolved in beef extract broth, glucose, dulcitol and maltose are always fermented to gas and acid.

Does not reduce trimethylamine oxide (Wood et al., Jour. Bact., *46*, 1943, 106).

Optimum temperature 37°C. Does not grow at 45.5°C (Stuart et al., Jour. Bact., *46*, 1943, 105).

Aerobic, facultative.

Serologically related to the mannitol-fermenting strains of *Shigella paradysenteriae*.

Source: Isolated in 1925 from a case of diarrhoea in Newcastle-on-Tyne, England.

Habitat: A cause of human dysentery.

4b. *Shigella paradysenteriae* (Type Manchester). (Downie, Wade and Young, Jour. Hyg., *33*, 1933, 196; *Bacillus dysenteriae* Flexner VI in part, Boyd, Trans. Roy. Soc. Trop. Med. and Hyg., *33*, 1940, 553.)

Characters as for Type Newcastle except that acid and gas are produced from mannitol. Does not produce gas from maltose.

Serologically related to the non-mannitol-fermenting strains of *Shigella paradysenteriae*.

Source: Five strains were isolated from cases of dysentery at Denton near Manchester, England. One strain came from a case of dysentery in Nigeria.

Habitat: A cause of human dysentery.

5. **Shigella alkalescens** (Andrewes) Weldin. (*Bacillus alkalescens* Andrewes, The Lancet, London, *194*, 1918, 560; *Bacterium alkalescens* Levine, Jour. Inf. Dis., *27*, 1920, 31; *Eberthella alkalescens* Bergey et al., Manual, 1st ed., 1923, 231; Weldin, Iowa State College Jour. Sci., *1*, 1927, 179; *Proshigella alkalescens* Borman, Stuart and Wheeler, Jour. Bact., *48*, 1944, 363.) From the chemical term, alkaline.

Rods: 0.5 by 1.0 to 1.5 microns, occurring singly and in pairs. Non-motile. Gram-negative.

Gelatin stab: No liquefaction.

Agar slant: Abundant, transparent, often iridescent growth.

Broth: Turbid.

Litmus milk: Acid, then alkaline.

Potato: Moderate, grayish growth.

Indole is formed.

Acid but no gas from glucose, xylose, rhamnose, maltose, mannitol and dulcitol. Sucrose is fermented by some strains. Does not attack lactose, dextrin or salicin.

Reduces trimethylamine oxide to trimethylamine (Wood et al., Jour. Bact., *46*, 1943, 106). In contrast to all other species of the genus, will also produce trimethylamine from choline (Wood and Keeping, Jour. Bact., *47*, 1944, 309).

Aerobic, facultative.

Optimum temperature 37°C. Grows at 45.5°C (Eijkman's reaction, Stuart et al., Jour. Bact., *46*, 1943, 105).

Not pathogenic. Not agglutinated by Shiga immune serum.

Source: From feces in cases of dysentery.

Habitat: Intestinal canal.

6. **Shigella pfaffii** (Hadley et al.) Weldin. (Bacillus der kanarienvögelseuche, Pfaff, Cent. f. Bakt., I Abt., Orig., *38*, 1905, 276; *Bacterium pfaffi* Hadley, Elkins and Caldwell, Rhode Island Agr. Exp. Sta. Bull. 174, 1918, 169; *Bacillus pfaffi* Hadley, Elkins and Caldwell, *ibid.*, 204; *Eberthella pfaffi* Bergey et al., Manual, 1st ed., 1923, 232; Weldin, Iowa State College Jour. Sci., *1*, 1927, 180.) Named for Dr. Franz Pfaff of Prague who isolated this species.

Description largely from Hadley et al. (*loc. cit.*, 180).

Rods: 0.5 by 1.0 to 2.0 microns, occurring singly. Non-motile. Gram-negative.

Gelatin colonies: Small, grayish, translucent.

Gelatin stab: No liquefaction.

Agar colonies: Small, yellowish-gray, homogeneous, translucent, entire. No odor.

Agar slant: Slight, yellowish-gray, translucent streak.

Broth: Turbid, with flocculent sediment (Pfaff, *loc. cit.*, 280).

Litmus milk: Unchanged.

Potato: Moderate, whitish streak.

Acid but no gas from glucose, fructose, arabinose, xylose, maltose, dextrin, salicin and mannitol. Does not attack lactose, sucrose, raffinose, inulin, adonitol or dulcitol.

Indole not formed.

No hydrogen sulfide produced.

Nitrites not produced from nitrates.

Pathogenic for canaries, sparrows, pigeons, white mice, guinea pigs and rabbits. Not pathogenic for chickens (Pfaff, *loc. cit.*, 280).

Aerobic, facultative.

Optimum temperature 37°C.

Source: First encountered in an epidemic of septicemia in canaries. Caused a necrotic enteritis.

Habitat: Not known from other sources.

7. **Shigella sonnei** (Levine) Weldin. (Duval's bacillus, Duval, Jour. Amer. Med. Assn., *43*, 1904, 381; Pseudodysentery bacillus E, Kruse, Deutsche med. Wchnschr., *23*, 1907, 292, 338; *Bacillus ceylonensis A*, Castellani, Jour. Hyg., 7, 1907, 1; Group III of Sonne, Sonne, Cent. f. Bakt., I Abt., Orig., *75*, 1915, 408; *Bacillus dispar* (in part) Andrewes, Lancet, *1*, 1918, 560 (see *Shigella ceylonensis* and *Shigella madampensis*); Bacillus of Sonne, Thjøtta, Jour. Bact., *4*, 1919, 355; *Bacterium sonnei* Levine, Jour. Inf. Dis., *27*, 1920, 31; *Bacillus dysenteriae* Sonne, Smith, Jour. Hyg., *23*, 1924, 94; Weldin, Iowa Sta. Coll. Jour. Sci., *1*, 1927, 182; *Castellanus krusecastellani* Cerruti, Jour. Trop. Med. and Hyg., *33*, 1930, 207; *Shigella paradysenteriae* var. *sonnei* Bergey et al., Manual, 4th ed., 1934, 393; *Proshigella sonnei* Borman, Stuart and Wheeler, Jour. Bact., *48*, 1944, 363.) Named for Dr. Carl Sonne, who worked with this organism.

Rods: Non-motile. Gram-negative.

Gelatin: No liquefaction.

Agar colonies: Cultures dissociable into two types: (1) Glistening surface, 2 mm in diameter in 24 hours, soft, grayish, edge entire; (2) Granular surface, 3 to 4 mm in diameter in 24 hours, soft, grayish, edge tending to spread unevenly, surface developing, after some days, papillae (daughter colonies) which are lactose-fermenting. Some colonies of type 1 change to type 2 on continued incubation. The colony types do not breed true.

Broth: Many authors stress the flocculent growth, associated with spontaneous agglutination in saline solution. These appear to be dependent on growth conditions and time of incubation.

Litmus milk: Acid and with about 50 per cent of strains coagulation. Coagulation tends to occur later than the fermentation of lactose in peptone water.

Indole is not produced.

Acid, but no gas, from lactose (about 2 per cent of strains are lactose-negative after 2 months incubation), glucose, fructose, maltose, galactose, rhamnose, mannitol, arabinose, raffinose and sucrose. No acid from dulcitol, inulin, inositol, adonitol, xylose (xylose is occasionally fermented) and salicin.

Fermentation of substances other than the monosaccharides may require days or weeks.

Reduces trimethylamine oxide to trimethylamine (Wood et al., Jour. Bact., *46*, 1943, 106).

Serologically *Shigella sonnei* is divisible into two types, which do not correspond with the colony types described above. Most freshly isolated strains absorb agglutinins completely from all *Shigella sonnei* antisera, while most stock strains absorb only partially from other than antisera of the second serological type. There exist minor serological relationships between *Shigella sonnei* and *Shigella paradysenteriae*, *Shigella alkalescens* and *Shigella madampensis*.

Optimum temperature 37°C. Grows at 45.5°C (Stuart et al., Jour. Bact., *46*, 1943, 105).

Source: From feces in cases of dysentery.

Habitat: A cause of mild dysentery in man; summer diarrhoea in children.

8. **Shigella equirulis** (de Blieck and van Heelsbergen) Edwards. (*Bacillus nephritidis equi* Meyer, Transvaal Dept. Agr. Rept. Gov. Bac., 1908–1909, 122; *Bacterium viscosum equi* Magnusson,

Svensk. Veterinartijdskr., 1917, 81; also see Jour. Comp. Path. and Therap., *32*, 1919, 143; *Bacillus equuli* van Straaten, Verslag van den Werkzaamheden der Rijksseruminrichting voor 1916–1917, Rotterdam, 1918, 75; *Bacterium pyosepticus equi* de Blieck and van Heelsbergen, Tydschr. v. Diergeneesk., *46*, 1919, 492; *Bacillus equirulis* de Blieck and van Heelsbergen, *ibid.*, 496; *Bacterium pyosepticum viscosum* Meissner, Deut. tierärztl. Wchnschr., *29*, 1921, 185; *Bacterium pyosepticum* (*viscosum*) *equi* Lütje, Deut. tierärztl. Wchnschr., *29*, 1921, 463; *Bacterium pyosepticum* (*viscosum*) Meissner and Berge, Deut. tierärztl. Wchnschr., *30*, 1922, 473; *Bacterium pyosepticum* Meissner, Deut. tierärtzl. Wchnschr., *31*, 1923, 348; *Bacterium pyosepticum equi* Landien, Inaug. Diss., Hanover, 1923; *Bacillus pyosepticus* Clarenberg, Ztschr. f. Infektskr. u. Hyg. d. Haust., *27*, 1924, 193; *Bacterium equi* Weldin and Levine, Abst. Bact., *7*, 1923, 13; *Eberthella viscosa* Snyder, Jour. Amer. Vet. Med. Assoc., *66*, 1925, 481; *Shigella equi* Weldin, Iowa Sta. Col. Jour. Sci., *1*, 1927, 121; *Shigella viscosa* Bergey et al., Manual, 3rd ed., 1930, 363; Edwards, Kentucky Agr. Exp. Sta. Res. Bul. 320, 1931.)

While awaiting further information, the binomial introduced by Edwards is used for this species although Haupt of Leipzig points out in a personal communication to Edwards (1934) that van Straaten's original name was *Bacillus equuli*. The binomial *Bacillus equirulis* is stated to have appeared first in the article by de Blieck and van Heelsbergen, *loc. cit.*

Description from Edwards (*loc. cit.*).

Rods: 0.3 to 0.4 by 0.4 to 0.8 micron, occurring singly, in chains and filaments. Young cultures (8 to 10 hrs.) frequently show long filaments and streptococcus-like chains as well as large, yeast-like bodies with projections. Rough mucoid colonies consist of short, oval rods. Smooth colonies contain long filaments and streptococcus-like chains. Rough colonies are always mucoid. Non-mucoid colonies are always smooth. Capsules described but uncertain. Non-motile. Gram-negative.

Gelatin colonies: Grayish-white, circular, translucent.

Gelatin stab: Nail-head, moderate growth along line of stab. No liquefaction.

Agar colonies: 3 to 5 mm at 48 hours. Semi-solid, tough, adherent, circular, grayish-white, smooth, moist, glistening. Rough variants and dwarf colonies.

Agar slant: Grayish-white, viscid growth, covering the surface. Viable 8 to 10 days.

Broth: Masses form on side of tube. At times a thin grayish pellicle. Grayish, tough, ropy sediment. Eventually diffuse turbidity which is highly viscous. Viability 2 to 4 weeks.

Litmus milk: Slowly acidified; slimy, viscid. Sometimes coagulation and reduction.

Potato: No visible growth.

Indole not formed.

Nitrites produced from nitrates.

Voges-Proskauer test negative.

Acid but no gas from glucose, fructose, xylose, lactose, galactose, maltose, sucrose, mannitol and raffinose. Dextrin usually fermented. No action in rhamnose, dulcitol, sorbitol or inositol. Usually no action in salicin, adonitol and arabinose.

Does not reduce trimethylamine oxide (Wood et al., Jour. Bact., *46*, 1943, 106).

Does not grow at 45.5°C (Stuart et al., Jour. Bact., *46*, 1943, 105).

Optimum temperature 37°C.

Aerobic, facultative.

Not pathogenic for small experimental animals. Produces abscesses and stiffening of the joints when injected subcutaneously in horses.

Serologically heterogeneous. Nothing is known of its antigenic relations to other members of the genus. Haupt writes in a personal communication that comparative serological studies indicate

that this species should be placed in the genus *Actinobacillus*.

Distinctive characters: Differentiation from *Shigella sonnei* is made on cultural and morphological grounds and immediate fermentation of lactose.

Source: Isolated from cases of joint-ill in foals.

Habitat: Causes joint-ill in foals.

9. **Shigella ceylonensis** (Castellani) Weldin. (*Bacillus ceylonensis B*, Castellani, Jour. Hyg., *7*, 1907, 1; *Bacillus dispar* (in part) Andrewes, Lancet, *1*, 1918, 560 (see *Shigella madampensis* and *Shigella sonnei*. Andrewes included in *Bacillus dispar* all lactose-fermenting members of the dysentery group); *Lankoides ceylonensis B*, Castellani and Chalmers, Man. Trop. Med., 3rd ed., 1919, 938; *Eberthella dispar* Bergey et al., Manual, 1st ed., 1923, 232 (see *Shigella madampensis*); Weldin, Iowa Sta. Coll. Jour. Sci., *1*, 1927, 182; *Castallanus castellanii* Cerruti, Jour. Trop. Med. and Hyg., *33*, 1930, 207.) Latinized, pertaining to Ceylon.

Rods: Non-motile. Gram-negative.

Morphology and colony characters indistinguishable from those of *Shigella dysenteriae*.

Gelatin not liquefied.

Litmus milk: Acid with coagulation.

Indole is formed.

Acid, but no gas, from lactose, glucose, fructose, sucrose, mannitol, dulcitol, maltose, xylose, arabinose, rhamnose, sorbitol, raffinose, dextrin and glycerol. Inulin, inositol, adonitol and salicin not fermented (salicin differentiates *Shigella ceylonensis* from *Bacterium coli anaerogenes* Lembke, Arch. f. Hyg., *26*, 1896, 299).

Substances other than the monosaccharides are characteristically fermented slowly.

Reduces trimethylamine oxide to trimethylamine (Wood et al., Jour. Bact., *46*, 1943, 106).

Pathogenic for guinea pigs and rabbits.

Serologically the organism is stated by Castellani to be homogeneous and completely different from *Shigella madampensis* and *Shigella sonnei*. The relations to other members of the dysentery group have not been stated.

Optimum temperature 37°C. Grows at 45.5°C (Stuart et al., Jour. Bact., *46*, 1943, 105).

Source: Isolated from the stools and intestines of persons suffering from dysentery.

Habitat: A cause of dysentery in man.

10. **Shigella madampensis** (Castellani) Weldin. (*Bacillus madampensis* Castellani, Cent. f. Bakt., I Abt., Orig., *65*, 1912, 262; *Bacillus dispar* (in part) Andrewes, Lancet, *1*, 1918, 560 (see *Shigella ceylonensis* and *Shigella sonnei*); *Lankoides madampensis* Castellani and Chalmers, Man. Trop. Med., 3rd ed., 1919, 938; *Bacterium dispar* Levine, Abst. Bact., *4*, 1920, 15; *Eberthella dispar* Bergey et al., Manual, 1st ed., 1923, 232 (see *Shigella ceylonensis*); Weldin, Iowa Sta. Coll. Jour. Sci., *1*, 1927, 181a; *Shigella dispar* Bergey et al., Manual, 3rd ed., 1930, 364; *Proshigella dispar* Borman, Stuart and Wheeler, Jour. Bact., *48*, 1944, 363.)

Neter (Bact. Rev., *6*, 1942, 26) combines *Shigella ceylonensis* and *S. madampensis* into a single species which he names *Shigella castellanii*.

Strains currently existing in various Type Collections as *Bacillus dispar* have biochemical properties indistinguishable from those described for *Shigella madampensis* (Glynn and Starkey, Jour. Bact., *37*, 1939, 315).

Rods: Non-motile. Gram-negative.

Morphology and colony characters indistinguishable from those of *Shigella dysenteriae*.

Gelatin not liquefied.

Indole is formed.

Litmus milk: Acid with coagulation.

Acid, but no gas, from lactose, maltose, sucrose, arabinose, xylose, glycerol, mannitol, rhamnose, glucose, fructose, galactose and dextrin. Dulcitol, salicin, inulin, inositol and adonitol not fermented.

Substances other than monosaccharides are characteristically fermented slowly.

Reduces trimethylamine oxide to trimethylamine (Wood et al., Jour. Bact., *46*, 1943, 106).

Serologically the organism is stated by Castellani to be homogeneous and completely different from *Shigella ceylonensis* and *Shigella sonnei*. According to Andrewes (*loc. cit.*), *Bacillus dispar* is serologically distinct from *Shigella alkalescens* and *Shigella paradysenteriae*. Fifteen strains (Glynn and Starkey, *loc. cit.*) from various sources, labelled *Bacillus dispar* and conforming to the above description, proved to be serologically heterogeneous.

Optimum temperature 37°C. Grows at 45.5°C (Stuart et al., Jour. Bact., *46*, 1943, 105).

Source: Isolated from human stools and intestines.

Habitat: Considered by Castellani to be a cause of colitis and cystitis.

11. Shigella septicaemiae (Bergey et al.) Bergey et al. (*Bacillus septicaemiae anserum exsudativae* Riemer, Cent. f. Bakt., I Abt., Orig., *37*, 1904, 648; *Eberthella septicaemiae* Bergey et al., Manual, 2nd ed., 1925, 250; Bergey et al., Manual, 3rd ed., 1930, 358.) Latinized, of septicemia.

Small rods: 0.5 by 1.5 to 2.0 microns, occurring singly, in pairs and in threads. Motile. Gram-negative.

Gelatin colonies: Small, white, circular.

Gelatin stab: Slight, infundibuliform liquefaction, becoming complete in several weeks.

Agar colonies: Circular, transparent, smooth, homogeneous, entire.

Agar slant: Soft, grayish-white streak, slightly viscid, becoming transparent.

Does not grow on Endo agar.

Broth: Slight, uniform turbidity, with slight pellicle formation.

Litmus milk: Unchanged.

Potato: No growth.

Blood serum: Yellowish-white streak, the medium becoming brownish and slowly liquefied.

Indole is formed after several days.

Slight acid and no gas from glucose. No acid from lactose.

Hydrogen sulfide is formed.

Not pathogenic for white mice, guinea pigs, chickens or pigeons. Mildly pathogenic for ducks.

Aerobic.

Optimum temperature 37°C.

Source: Isolated from blood, exudates and all of the internal organs of geese.

Habitat: Cause of a fatal septicemia in young geese.

Appendix: The following species are also found in the literature. Many are incompletely described.

Bacillus coli dysentericum Ciechanowski and Nowak. (Cent. f. Bakt., I Abt., Orig., *23*, 1898, 445.) From a case of dysentery.

Bacillus dysenteriae Migula. (Bacillus of Japanese dysentery, Ogata, Cent. f. Bakt., *11*, 1892, 264; *Bacillus dysenteriae liquefaciens* Kruse, in Flügge, Die Mikroorganismen, 3 Aufl., *2*, 1896, 284; *Bacterium dysenteriae liquefaciens* Chester, Ann. Rept. Del. Col. Agr. Exp. Sta., *9*, 1897, 102; Migula, Syst. d. Bakt., *2*, 1900, 641; not *Bacillus dysenteriae* Shiga, Cent. f. Bakt., I Abt., *24*, 1898, 817; not *Bacillus dysenteriae* Hiss and Russell, Medical News, *82*, 1903, 289; not *Bacillus dysenteriae* Strong, Jour. Amer. Med. Assoc., *35*, 1906, 498; not *Bacillus dysenteriae* Sonne, Smith, Jour. Hyg., *23*, 1924, 94.) From a case of Japanese dysentery. Motile. Gram-positive.

Bacillus dysentericus Trevisan. (Bacillus der Dysenterie, Klebs, Cent. f. Bakt., *2*, 1887, 248; Trevisan, I generi e le specie delle Batteriacee, 1889, 14; not *Bacillus dysentericus* Ruffer and Willmore, Brit. Med. Jour., *2*, 1909, 862.) From feces.

Bacterium pseudodysentericum Kruse. (Kruse, Deutsche med. Wchnschr., *27*, 1901, 370, 386; *Escherichia pseudodysenteriae* Bergey et al., Manual, 1st ed., 1923, 198.) From feces. Motile.

Bacterium wakefield Berger. (Jour.

Hyg., *44*, 1945, 116–119.) From feces. A non-mannitol-fermenting organism of the Flexner group. Wheeler and Stuart (Jour. Bact., *51*, 1946, 324) regard this as an anaerogenic paracolon.

Shigella albofaciens (Castellani) Hauduroy et al. (*Bacillus albofaciens* Castellani, Meetings of the Ceylon Branch of the British Medical Association, 1905; Hauduroy et al., Dict. d. Bact. Path., 1937, 482.)

Shigella arabinotarda, types A and B, Christensen and Gowen. (Jour. Bact., *47*, 1944, 171–176.) From cases of dysentery in U. S. Army in Tunisia. A lactose-negative, mannitol-negative *Shigella*.

Shigella bienstockii (Schroeter) Bergey et al. (Bacillus III, Bienstock, Ztschr. f. klin. Med., *8*, 1884; *Bacillus coprogenes parvus* Flügge, Die Mikroorganismen, 2 Aufl., 1886, 269; *Bacillus bienstockii* Schroeter, Kryptogamen Flora von Schlesien, *3*, 1, 1886, 163; *Bacillus parvus* Trevisan, I generi e le specie delle Batteriacee, 1889, 15; not *Bacillus parvus* Neide, Cent. f. Bakt., II Abt., *12*, 1904, 344; *Bacterium coprogenes parvus* Chester, Ann. Rept. Del. Col. Agr. Exp. Sta., *9*, 1897, 85; *Bacterium bienstockii* Chester, Man. Determ. Bact., 1901, 144; *Eberthella bienstockii* Bergey et al., Manual, 1st ed., 1923, 227; Bergey et al., Manual, 3rd ed., 1930, 360.) From feces.

Shigella douglasi (Castellani and Chalmers) Hauduroy et al. (*Bacillus douglasi* Castellani and Chalmers, Man. Trop. Med., 3rd ed., 1919, 946; Hauduroy et al., Dict. d. Bact. Path., 1937, 484.)

Shigella etousae Heller and Wilson. (Jour. Path. and Bact., *58*, 1946, 98.) From dysentery outbreak in an army camp in England.

Shigella faecaloides (Castellani) Hauduroy et al. (*Bacillus faecaloides* Castellani, 1915; see Castellani and Chalmers, Man. Trop. Med., 3rd ed., 1919, 946; Hauduroy et al., Dict. d. Bact. Path., 1937, 488.)

Shigella giumai (Castellani) Hauduroy et al. (*Bacillus giumai* Castellani, Cent. f. Bakt., I Abt., Orig., *65*, 1912, 264; *Wesenbergus giumai* Castellani and Chalmers, Man. Trop. Med., 3rd ed., 1919, 940; *Bacterium giumai* Weldin and Levine, Abst. Bact., *7*, 1923, 15; *Salmonella giumai* Bergey et al., Manual, 1st ed., 1923, 220; Hauduroy et al., Dict. d. Bact. Path., 1937, 488.)

Shigella lunavensis (Castellani) Hauduroy et al. (*Bacillus lunavensis* Castellani, Cent. f. Bakt., I Abt., Orig., *65*, 1912, 264; *Bacterium lunavensis* Weldin and Levine, Abst. Bact., *7*, 1923, 16; Hauduroy et al., Dict. d. Bact. Path., 1937, 489.) From feces.

Shigella metadysenterica var. *A*, *B*, *C*, and *D* (Castellani) Hauduroy et al. (*Bacillus metadysentericus* var. *A*, *B*, *C*, and *D*, Castellani, 1904; see Castellani and Chalmers, Man. Trop. Med., 3rd ed., 1919, 946; *Dysenteroides metadysentericus* var. *A*, *B*, *C*, and *D*, Castellani and Chalmers, Ann. Inst. Past., *34*, 1920, 607; *Castellanus metadysentericus* Castellani, 1930; Hauduroy et al., Dict. d. Bact. Path., 1937, 489.) From cases of dysentery.

Shigela negombensis (Castellani) Hauduroy et al. (*Bacillus negombensis* Castellani, Cent. f. Bakt., I Abt., Orig., *65*, 1912, 262; Hauduroy et al., Dict. d. Bact. Path., 1937, 490.)

Shigella oxygenes (Ford) Bergey et al. (*Bacterium oxygenes* Ford, Studies from the Royal Victoria Hospital, Montreal, *1*, No. 5, 1903, 47; *Eberthella oxygenes* Bergey et al., Manual, 1st ed., 1923, 228; Bergey et al., Manual, 3rd ed., 1930, 360.) From feces.

Shigella piscatora Bois and Roy. (Naturaliste Canadien, *71*, 1945, 259.) From the intestine of a codfish (*Gadus callarias L.*).

Shigella tangallensis (Castellani) Hauduroy et al. (*Bacillus tangallensis* Castellani, Cent. f. Bakt., I Abt., Orig., *65*, 1912, 266; Hauduroy et al., Dict. d. Bact. Path., 1937, 497.) From feces.

Shigella tarda (Castellani) Hauduroy et al. (*Bacillus tardus* Castellani, 1917; see Castellani and Chalmers, Man. Trop. Med., 3rd ed., 1919, 954; Hauduroy et al., Dict. d. Bact. Path., 1937, 497.)

FAMILY XI. PARVOBACTERIACEAE RAHN.*

(Cent. f. Bakt., II Abt., *96*, 1937, 281.)

Small, motile or non-motile rods. Gram-negative. Some will grow on ordinary media, but the majority either require or grow better on media containing body fluids or growth-promoting substances. Some invade living tissues. Usually do not liquefy gelatin. No visible gas formed in the fermention of carbohydrates. Infection in some cases may take place by penetration of organisms through mucous membranes or skin. Parasitic to pathogenic on warm-blooded animals, including man.

Key to the tribes of family **Parvobacteriaceae.**

I. Usually grow on ordinary media.
  A. Aerobic to facultative anaerobic.
    1. Show bipolar staining. Majority ferment carbohydrates.
      Tribe I. *Pasteurelleae*, p. 545.
    2. Do not show bipolar staining. None ferment carbohydrates.
      Tribe II. *Brucelleae*, p. 560.
  B. Anaerobic.
      Tribe III. *Bacteroideae*, p. 564.
II. On first isolation dependent on some factor or factors contained in blood or plant tissues. Aerobic to anaerobic.
      Tribe IV. *Hemophileae*, p. 584.

TRIBE I. PASTEURELLEAE CASTELLANI AND CHALMERS.

(Man. Trop. Med., 3rd ed., 1919, 943.)

Small, motile or non-motile, ellipsoidal to elongated rods showing bipolar staining.

Key to the genera of tribe **Pasteurelleae.**

I. Milk not coagulated.
  A. Causes hemorrhagic septicemia, pseudotuberculosis, tularemia or plague.
      Genus I. *Pasteurella*, p. 546.
II. Milk coagulated slowly and sometimes digested.
  A. Causes glanders or glanders-like infections.
      Genus II. *Malleomyces*, p. 554.
III. Milk unchanged to slightly acid.
  A. Associated with actinomycosis in cattle and in man.
      Genus III. *Actinobacillus*, p. 556.

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* Revised by Prof. E. G. D. Murray, McGill University, Montreal, Canada with the collaboration of Prof. Karl F. Meyer, Hooper Foundation, San Francisco, California; Prof. W. A. Hagan, Cornell University, Ithaca, New York; Dr. Alice C. Evans and Dr. Margaret Pittman, National Institute of Health, Washington, D. C.; Prof. I. F. Huddleson, Michigan State College, East Lansing, Michigan; and others, December, 1938.

Genus I. **Pasteurella** *Trevisan.**

(*Octopsis* Trevisan, Atti della Accad. Fisio-Medico-Statistica, Milano, Ser. 4, *3*, 1885, 102; Trevisan, Rendiconti Reale Instituto Lombardo di Scienze e Lettere, 1887, 94; *Coccobacillus* Gamaleïa, Cent. f. Bakt., *4*, 1888, 167; *Eucystia* Enderlein, Sitzber. Gesell. Naturf. Freunde, Berlin, 1917, 317.) Named for Louis Pasteur, the French scientist.

Small, Gram-negative, ellipsoidal to elongated rods showing bipolar staining by special methods; aerobic, facultative; may require low oxidation-reduction potential on primary isolation; majority ferment carbohydrates but produce only a small amount of acid; no or slight lactose fermentation; no gas production; gelatin not liquefied; milk not coagulated; parasitic on man, other mammals and birds.

The type species is *Pasteurella multocida* (Lehmann and Neumann) Rosenbusch and Merchant.

Key to the species of genus **Pasteurella.**

I. Growth on ordinary media. Growth in milk.
  A. Non-motile and non-flagellated at 18° to 26°C. No change or slight acid in milk without coagulation.
    1. Indole and H_2S produced. No growth in bile. Sorbitol fermented. No hemolysis on blood agar.
      1. *Pasteurella multocida.*
    2. Indole not formed. Hemolysis produced on blood agar.
      2. *Pasteurella hemolytica.*
    3. Neither indole nor H_2S produced. Growth in bile. Sorbitol not fermented. No hemolysis.
      3. *Pasteurella pestis.*
  B. Motile and flagellated at 18° to 26°C. Milk alkaline. Hydrogen sulfide produced. Indole not formed.
      4. *Pasteurella pseudotuberculosis.*
II. No growth on plain agar or in liquid medium without special enrichment. No growth in milk.
      5. *Pasteurella tularensis.*

1. **Pasteurella multocida** (Lehmann and Neumann) Rosenbusch and Merchant. (Virus der Wildseuche, Hueppe, Berlin. klin. Wochnschr., *23*, 1886, 797; Bactérie ovoide, Lignières, Recueil de Méd. Vétér., *75*, 1898, 836 (Bull. Soc. Centr. Méd. Vétér., N. S. *60*, 1898, 836); *Bacillus septicaemiae haemorrhagicae* Sternberg, Man. of Bact., 1893, 408; *Bacterium septicaemiae hemorrhagicae* Lehmann and Neumann, Bakt. Diag., 2 Aufl., *2*, 1899, 194; *Bacterium multocidum* Lehmann and Neumann, *ibid.*, 196; *Bacillus plurisepticus* and *Bacterium avicidum* Kitt, in Kolle and Wassermann, Handb. d. path. Mikroorg., 1 Aufl., *2*, 1903, 562; *Bacillus pleurisepticus* Jordan, General Bact., 1st ed., 1908, 289; *Bacillus bipolaris septicus* Hutyra, in Kolle and Wassermann, Handb. d. path. Mikroorg., 2 Aufl., *6*, 1913, 67; *Bacillus bipolaris plurisepticus* Hutyra, *ibid.*; *Pasteurella septica* Topley and Wilson, Princip. Bact. and Immun., 1st ed., *1*, 1931, 488;

* Rearranged by Mrs. Eleanore Heist Clise, New York State Experiment Station, Geneva, New York, in accordance with the suggestions of Mr. Philip C. Harvey and Dr. Mark Welsh, Pearl River, New York, November, 1945.

Pasteurella pluriseptica Gay et al., Agents of Disease and Host Resistance, 1935, 730; Rosenbusch and Merchant, Jour. Bact., *37*, 1939, 85.) From Latin, killing many.

The following are regarded as identical with the above but are arranged here according to source:

Pasteurella bollingeri Trevisan. (Microparasiten bei eine neue Wild- und Rinderseuche, Bollinger, Über eine neue Wild- und Rinderseuche unsw., München, 1878; *Bacterium bipolare multocidum* Kitt, Sitz. Gesell. Morphol. u. Physiol., München, *1*, 1885, 24; Trevisan, I generi e le specie delle Batteriacee, 1889, 21; *Bacillus bovisepticus* Kruse, in Flügge, Die Mikroorganismen, 3 Aufl., *2*, 1896, 421; *Bacterium bovisepticus* Chester, Ann. Rept. Del. Coi. Agr. Exp. Sta., *9*, 1897, 81; *Bacterium multocidum* Lehmann and Neumann, Bakt. Diag., 2 Aufl., *2*, 1899, 196; La Pasteurella bovine, Lignières, Recueil de Méd. Vétér., *77*, 1900, 537; *Bacillus bipolaris bovisepticus* Hutyra, in Kolle and Wassermann, Handb. d. path. Mikroorg., 2 Aufl., *6*, 1913, 67; *Pasteurella boviseptica* Holland, Jour. Bact., *5*, 1920, 224; *Pasteurella bovium* Hutyra, in Kolle, Kraus und Uhlenhuth, Handb. d. path. Mikroorg., 3 Aufl., *6*, 1927–1929, 487; *Pasteurella ferarum* Hauduroy et al., Dict. d. Bact. Path., 1937, 316.) From domestic cattle and deer.

Pasteurella avicida (Gamaleïa) Trevisan. (Microbe du cholera des poules, Pasteur, Compt. rend. Acad. Sci., Paris, *90*, 1880, 239, 952 and 1030; Granules of fowl cholera, Salmon and Th. Smith, U. S. Dept. Agr. Ann. Rept., 1880, 438; *Micrococcus cholerae gallinarum* Zopf, Die Spaltpilze, 3 Aufl., 1885, 57; *Octopsis cholerae gallinarum* Trevisan, Atti della Accad. Fisio-Medico-Statistica, Milano, Ser. 4, *3*, 1885, 102; *Bacillus cholerae gallinarum* Flügge, Die Mikroorganismen, 2 Aufl., 1886, 253; *Bacterium cholerae gallinarum* Schroeter, Kryptogamen Flora von Schlesien, *3*, 1, 1886, 155; Hühnercholerabacterien, Kitt, Cent. f. Bakt., *1*, 1887, 305; *Pasteurella cholerae gallinarum* Trevisan, Rendiconti Reale Instituto Lombardo di Scienze e Lettere, 1887, 94; *Coccobacillus avicidus* Gamaleïa, Cent. f. Bakt., *4*, 1888, 167; Trevisan, I generi e le specie delle Batteriacee, 1889, 21; *Bacterium avicidum* Kitt, according to Chester, Man. Determ. Bact., 1901, 135; *Bacterium cholerae* Chester, *idem*; *Bacillus avisepticus* and *Bacterium avisepticum* Kitt, in Kolle and Wassermann, Handb. d. path. Mikroorg., 1 Aufl., *2*, 1903, 544; not *Bacillus avisepticus* Chester, *loc. cit.*, 220; *Pasteurella avium* Kitt, *loc. cit.*, 562; *Pasteurella gallinae* Besson, Practical Bacteriology, London and New York, 1913, 447; *Pasteurella cholerae-gallinarum* Winslow et al., Jour. Bact., *2*, 1917, 561; *Bacillus cholerae-gallinarum* Holland, Jour. Bact., *5*, 1920, 217; *Pasteurella aviseptica* Holland, *ibid.*, 224.) From fowls.

Pasteurella cuniculicida (Flügge) Trevisan. (Septicämiebacterien, Gaffky, Mit. kaiserl. Gesundheitsamte, *1*, 1881, 98; *Bacillus cuniculicida* Flügge, Die Mikroorganismen, 2 Aufl., 1886, 251; Trevisan, I generi e le specie delle Batteriacee, 1889, 21; *Bacterium septichaemiae* Schroeter, Kryptogamen Flora von Schlesien, *3*, 1, 1889, 155; *Bacterium cuniculicida* Chester, Ann. Rept. Del. Col. Agr. Exp. Sta., *9*, 1897, 80; not *Bacterium cuniculicida* Chester, Man. Determ. Bact., 1901, 140; *Bacillus cunicuIisepticus* Kitt, in Kolle and Wassermann, Handb. d. path. Mikroorg., 1 Aufl., *2*, 1903, 562; *Bacterium lepisepticum* Ferry and Hoskins, Jour. Lab. and Clin. Med., *5*, 1920, 311; *Bacillus bipolaris septicus* and *Bacillus lepisepticus* Ford, Textb. of Bact., 1927, 591; *Pasteurella lepiseptica* Holland, Jour. Bact., *5*, 1920, 221; *Pasteurella cuniculi* Schütze, Med. Res. Council, Syst. of Bact., London, *4*, 1929, 469; *Bacterium leporisepticum* Hauduroy et al., Dict. d. Bact. Path., 1937, 314.) From rabbits.

Pasteurella suilla Trevisan. (Rothlaufstabchen, Loeffler, Arb. kaiserl. Ge-

sundheitsamte, *1*, 1886, 51; Rothlaufbacillen, Schütz, *ibid.*, 74; Bacillus of swine plague, Salmon, Rept. U. S. Dept. Agr., Bur. An. Ind., 1886, 87; *Bacillus parvus ovatus* Flügge, Die Mikroorganismen, 2 Aufl., 1886, 273; Trevisan, Reale Instituto Lombardo d. Sci. e Let. Rend., Ser. 2, *20*, 1887, 94; *Bacterium suicida* Migula, in Engler and Prantl, Natürl. Pflanzenfam., *1*, 1a, 1895, 27; *Bacillus suisepticus* Kruse, in Flügge, Die Mikroorganismen, 3 Aufl., *2*, 1896, 419; *Bacterium suisepticus* Chester, Ann. Rept. Del. Col. Agr. Exp. Sta., *9*, 1897, 80; La Pasteurella porcine, Lignières, Recueil de Méd. Vétér., *77*, 1900, 391; *Pasteurella suiseptica* Holland, Jour. Bact., *5*, 1920, 220; *Pasteurella suum* Hutyra, in Kolle, Kraus and Uhlenhuth, Handb. d. path. Mikroorg., 3 Aufl., *6*, 1927–1929, 487.) From swine.

Bacterium bovicida Migula. (Microbo del barbone dei bufali, Oreste Armanni, Atti. d. R. Istit. d'incoragg. alle scienze natur. ecenom. e technol., 1887; Letta nella tornata Accad., Sept. 16, 1886; Cent. f. Bakt., *2*, 1887, 50; Atti della Commissione per le malattie degli animali, *121*, 1887; Migula, Syst. d. Bakt., *2*, 1900, 366; *Pasteurella bubalseptica* Kelser, Man. Vet. Bact., 1st ed., 1927, 195; *Bacillus bubalsepticus* Kelser, *ibid.*; *Bacillus bipolaris bubalisepticus* Hauduroy et al., Dict. d. Bact. Path., 1937, 312.) From buffaloes.

Pasteurella vituliseptica (Kitt) Ford. (*Bacillus vitulisepticus* Kitt, in Kolle and Wassermann, Handb. d. path. Mikroorg., 1 Aufl., *2*, 1903, 562; *Bacterium vitulisepticum* Lehmann and Neumann, Bakt. Diag., 5 Aufl., *2*, 1912, 282; Ford, Textb. of Bact., 1927, 597.) From calves.

Pasteurella muricida Meyer and Batchelder. (Meyer and Batchelder, Jour. Inf. Dis., *39*, 1926, 386; *Pasteurella muriseptica* Topley and Wilson, Princip. Bact. and Immun., 1st ed., *1*, 1931, 482; not *Pasteurella muriseptica* Bergey et al., 1st ed., 1923, 265 (*Bacillus murisepticus* Flügge, Die Mikroorganismen, 2 Aufl., 1886, 250; *Erysipelothrix muriseptica* Bergey et al., Manual, 2nd ed., 1925, 380).) From wild rats.

Bacillus bipolaris der malignen Meerschweinchen-Phlegmasie of Heymann and Kyriasides, Ztschr. f. Hyg., *114*, 1932, 119 (*Klebsiella caviae* Hauduroy et al., Dict. d. Bact. Path., 1937, 261) is stated by the original authors to be closely related to this organism.

Plasaj and Pribram (Cent. f. Bakt., I Abt., Orig., *87*, 1921, 1) also present a classification of the hemorrhagic septicemia bacteria.

Description from Schütze (Med. Res. Council, Syst. of Bact., London, *4*, 1929, 451) who prepared it from studies of 230 strains described by 17 authors during the years 1908–1926.

Short ellipsoidal rods: 0.3 to 1.25 microns in length, occurring singly, in pairs, rarely in chains. Show bipolar staining. Non-motile. Gram-negative.

Gelatin: No liquefaction.

Agar: Fine translucent growth. Characteristic odor.

Broth: Uniform turbidity. Characteristic odor.

Milk: No change in reaction. No coagulation.

Potato: No visible growth.

Indole is formed.

Nitrites are produced from nitrates.

Hydrogen sulfide is produced.

No hemolysis on blood agar.

Acid but no gas from glucose, mannitol (usually), sucrose, fructose, sorbitol, galactose, mannose, xylose (usually) and trehalose (usually). No acid from lactose, dulcitol, arabinose (usually), amygdalin, maltose (usually), raffinose, rhamnose, adonitol, dextrin, inulin, glycerol, salicin (usually) or erythritol.

Optimum temperature 37°C. Killed at temperatures above 45°C.

Aerobe to facultative anaerobe.

Three serological types have been found on the basis of agglutination tests (Little and Lyon, Amer. Jour. Vet. Res., *4*, 1943, 110).

Virulent for laboratory animals, especially mice and rabbits.

Distinctive characters: Grows on ordinary media. Bile salts inhibit growth.

Source: From numerous domestic animals and fowls, including cat, dog, cattle, horse, goat, sheep, pig, rabbit, chicken, and from reindeer, buffalo, rat, etc.

Habitat: The cause of hemorrhagic septicemia in birds and mammals.

2. **Pasteurella hemolytica** Newsom and Cross. (Jour. Amer. Vet. Med. Assoc., *80* (N.S. *33*), 1932, 715.) From M. L., hemolytic.

Bipolar staining.

Blood agar: Hemolysis.

Indole not formed.

Acid from dextrin, fructose, galactose, glucose, glycerol (usually), inositol, lactose (usually), maltose, mannitol, raffinose, sorbitol, sucrose and xylose. No acid from arabinose, dulcitol, inulin, mannose, rhamnose or salicin.

No cross-agglutination between *Pasteurella multocida* and this species.

Avirulent for rabbits.

Source: Twenty strains isolated from pneumonia in sheep and cattle.

Habitat: Occurs in pneumonia of sheep and cattle.

3. **Pasteurella pestis** (Lehmann and Neumann) Holland. (Bacille de la peste, Yersin, Ann. Inst. Past., *8*, 1894, 666; Pest Bacillus, Aoyama, Ztschr. f. Hyg., *21*, 1895, 165; *Bacterium pestis* Lehmann and Neumann, Bakt. Diag., 1 Aufl., *2*, 1896, 194; *Bacillus pestis bubonicae* Kruse, in Flügge, Die Mikroorganismen, 3 Aufl., *2*, 1896, 429; *Bacterium pestis bubonicae* Chester, Ann. Rept. Del. Col. Agr. Exp. Sta., *9*, 1897, 81; *Bacillus pestis* Migula, Syst. d. Bakt., *2*, 1900, 749; *Eucystia pestis* Enderlein, Sitzber. Gesell. Naturf. Freunde, Berlin, 1917, 317; Holland, Jour. Bact., *5*, 1920, 219; *Coccobacillus yersini* Neveu-Lemaire, Précis Parasitol. Hum., 5th ed., 1921, 20.) From Latin *pestis*, plague.

Rods: 1.0 by 2.0 microns, occurring singly. Non-motile. Polar staining. Characteristic bladder, safety-pin and ring involution forms. Gram-negative.

Gelatin colonies: Flat, gray, with granular margin.

Gelatin stab: Flat surface growth. Arborescent growth in stab. No liquefaction.

Agar colonies: Grayish-white, translucent, irridescent, undulate.

Agar slant: Growth grayish, viscid, thin, moist, translucent. Growth slow, favored by the addition of blood or sodium sulfite.

Broth: Turbid or clear with flocculi in the fluid. Old cultures show a pellicle with streamers into the fluid (stalactites). Becomes alkaline more slowly than *Pasteurella pseudotuberculosis*. See Bessonowa and Lenskaja, Cent. f. Bakt., I Abt., Orig., *119*, 1930, 430.

Litmus milk: Slightly acid or unchanged. No coagulation.

Potato: Scanty, grayish growth.

Indole not formed.

Lactose and rhamnose not attacked. Variable action on glycerol.

Nitrites are produced from nitrates.

Temperature relations: Optimum 25° to 30°C. Minimum 0°C. Maximum 43° to 45°C.

Aerobic, facultative.

Source: Buboes, blood, pleural effusion, spleen and liver of infected rodents and man. Sputum in pneumonic plague. Infected fleas.

Habitat: The causative organism of plague in man, rats, ground squirrels and other rodents. Infectious for mice, guinea pigs and rabbits. Transmitted from rat to rat and from rat to man by the infected rat flea.

Note: *Pasteurella pestis* and *Pasteurella pseudotuberculosis* are not definitely distinguishable by serological methods (Schütze, Med. Res. Council, Syst. of Bact., London, *4*, 1929, 478, and Wu Lien-teh, in Chun, Pollitzer and Wu, "Plague," National Quarantine Service, Shanghai, 1936). Malachite-green broth slowly decolorized by *Pasteurella pestis*

and quickly by *P. pseudotuberculosis*; same for methylene blue, Janus green and thionin. No growth on Bessonowa media (pH 5.9). See *Yersinia*, p. 703.

4. **Pasteurella pseudotuberculosis** (Eisenberg) Topley and Wilson. (Bacillus der pseudotuberculose, Pfeiffer, Ueber die bacilläre Pseudotuberculose bei Nagetieren, Leipzig, 1889; *Bacillus pseudotuberculosis* Eisenberg, Bakt. Diag., 3 Aufl., 1891, 294; *Streptobacillus pseudotuberculosis rodentium* Preisz, Ann. Inst. Past., *8*, 1894, 231; *Bacterium pseudotuberculosis rodentium* Lehmann and Neumann, Bakt. Diag., 1 Aufl., *2*, 1896, 362; *Bacillus pseudotuberculosis rodentium* Lehmann and Neumann, *ibid.*, 429; *Bacterium pseudotuberculosis* Migula, Syst. d. Bakt., *2*, 1900, 374; *Corynebacterium rodentium* Bergey et al., Manual, 1st ed., 1923, 386; *Corynebacterium pseudotuberculosis* Bergey et al., Manual, 2nd ed., 1925, 394; Topley and Wilson, Princip. Bact. and Immun., 1st ed., *2*, 1931, 825; *Corynebacterium pseudotuberculosis rodentium* Kelser, Man. Vet. Bact., 2nd ed., 1933, 319; *Malleomyces pseudotuberculosis rodentium* Pribram, Klassifikation d. Schizomyceten, 1933, 93.) Latinized, false tuberculosis.

Bacillus tuberculosis zoogloeicae Malassez and Vignal (Ann. de Physiol., 1883, 370) is considered identical with this species by Hauduroy et al. (Dict. d. Bact. Path., 1937, 162).

The original tabular description by Eisenberg, Bakt. Diag., 3 Aufl., 1891, 294 is very incomplete. Description taken from Topley and Wilson, Princip. Bact. and Immun., 2nd ed., 1936, 607 and Bessonowa, Lenskaja and Molodtzowa, Office Internat. d'Hyg. Publ., *29*, 1937, 2106.

Small rods: Variable in size and shape. Ellipsoidal or coccoid forms 0.8 by 0.8 to 2.0 microns, with rounded ends, occurring singly. Rod-shaped forms 0.6 by 1.5 to 5.0 microns, with rounded ends, occurring singly, in groups or in short chains. Occasionally long curved filaments. Motile (Weitzenberg, Cent. f. Bakt., I Abt., Orig., *133*, 1935, 343). Non-acid-fast. Gram-negative.

Gelatin stab: After 7 days at 22°C, good filiform growth extending to bottom of tube. No liquefaction.

Agar colonies: After 24 hours at 37°C, circular, 0.5 to 1.0 mm in diameter, umbonate, granular, translucent, grayish-yellow, butyrous; edge entire; dull, finely granular or beaten-copper surface; differentiated into a raised, more opaque center and a flat, clearer periphery with radial striation.

Agar slant: After 48 hours at 37°C, growth moderate, confluent, raised, grayish-yellow, translucent, with glistening, wavy or beaten-copper surface and an irregularly lobate edge.

Blood agar plate: Good growth. No hemolysis.

Broth: After 24 hours at 37°C, moderate growth with moderate turbidity which later clears. Viscous sediment. Incomplete surface and ring growth. Becomes alkaline more rapidly than *Pasteurella pestis*.

Potato: After 7 days at 22°C, a thin yellowish membrane which later turns brown.

Indole not formed.

Litmus milk: Usually slightly alkaline.

Nitrites produced from nitrates.

Ammonia is produced.

Acid but no gas from glucose, maltose, mannitol, salicin, arabinose, xylose, rhamnose and glycerol. Sometimes acid from sucrose.

Hydrogen sulfide produced.

Catalase positive.

Methyl red positive.

Methylene blue is reduced.

Voges-Proskauer test negative.

Temperature relations: Optimum 30°C. Minimum 5°C. Maximum 43°C. Thermal death point 60°C for ten minutes.

Pathogenicity: The cause of spontaneous disease in rabbits, rats and guinea pigs. Infectious for mice, rats, dogs, cats and horses.

Aerobic, facultative.

Source: From a guinea pig inoculated with material from a horse suspected of having glanders.

Habitat: Lesions in natural disease in animals. Causes pseudotuberculosis in rodents, especially guinea pigs.

5. **Pasteurella tularensis** (McCoy and Chapin) Bergey et al. (*Bacterium tularense* McCoy and Chapin, Jour. Inf. Dis., *10*, 1912, 61; McCoy and Chapin, Public Health Bull. 53, U. S. Treas. Dept., Public Health Service, 1912, 17; *Bacillus tularense* Vail, The Ophthalmic Record, 23, 1914, 487; also Francis, U. S. Hygienic Lab. Bull. 130, 1922; Bergey et al., Manual, 1st ed., 1923, 267; *Brucella tularensis* Topley and Wilson, Princip. Bact. and Immun., 1st ed., *1*, 1931, 509; *Coccobacterium tularense* Galli-Valerio, Schweiz. med. Wochnschr., *68*, 1938, 1206.) From Tulare, the county in California in which the disease was first observed.

Description taken from McCoy and Chapin (*loc. cit.*) and Francis (*loc. cit.*). Further revision by Francis, 1947.

Equal numbers of cocci and rods; 0.2 by 0.2 to 0.7 micron, occurring singly. Bipolar staining may occur. Capsules rare or absent. Extremely pleomorphic (Hesselbrock and Foshay, J. Bact. 49, 1945, 209) Non-motile. Gram-negative.

No growth on plain agar or in liquid media without special enrichment. (Tamura and Gibby, J. Bact. 45, 1943, 361) Filterable through Berkefeld filters.

Growth occurs on coagulated egg-yolk (McCoy and Chapin, *loc. cit.*), on blood-glucose-cystine agar (Francis, *loc. cit.*), on blood agar, glucose-blood agar and glucose serum agar. The addition of fresh sterile rabbit spleen to the surface of the last three media favors the growth of the organism.

Forms minute viscous colonies after 2 to 5 days which may attain a diameter of 4 mm if well separated. Growth readily emulsifiable.

Growth on blood media is gray. May cause green discoloration of the blood.

Rough, smooth and mucoid variants have not been reported.

Slight acid without gas may be produced from glucose, glycerol, maltose, mannose, fructose and dextrin.

Growth soluble in sodium ricinoleate.

Hydrogen sulfide produced in a cystine medium.

Aerobic. No growth anaerobically.

Optimum temperature 37°C. Thermal death point 56°C for ten minutes. Survives best at low temperatures, even −70°C.

Pathogenicity: Penetrates unbroken skin to cause infection. Buboes and areas of necrosis produced in human and animal tissue. Infectious for man and most rodents, including rabbits, guinea pigs, rats, mice, squirrels, ground hogs, muskrats, beavers, water rats and lemmings.

Source: Originally isolated from California ground squirrels and later from more than 30 other forms of wild life in the United States and elsewhere. Found in lesions in man and animals with natural or experimental infections. Especially the liver, blood, lymph nodes, and spleen of animals.

Habitat: The cause of tularemia in man and transmitted from wild animals to man by blood-sucking insects, by contact with infected animals, or by drinking water. Disease known in North America, Japan, Russia, Norway, Sweden, Austria, Turkey, Czechoslovakia and Central Germany. See Burroughs, Holdenreid, Longanecker and Meyer, Jour. Inf. Dis., *76*, 1945, 115 for a complete list of known vertebrate hosts.

Appendix: The following organisms may be identical with some of those listed above or related to them:

Bacillus coscoroba Trétrop. (Trétrop, Ann. Inst. Past., *14*, 1900, 224; not *Bacillus coscoroba* MacConkey, Jour. Hyg., *6*, 1906, 397.) The cause of swan cholera in the Antwerp Zoological Garden. Trétrop's description is that of a *Pasteurella* as is pointed out by Castellani

and Chalmers (Man. Trop. Med., 3rd ed., 1919, 941). The organism described by Trétrop clearly was not the same as that in the culture sent by Binot of the Pasteur Institute to MacConkey and described by him (*loc. cit.*) as a member of the coliform group. Because of MacConkey's studies, the Binot culture has been accepted as determining the nature of *Bacillus coscoroba* in many subsequent studies of the coliform group, e. g., Bergey and Deehan, Jour. Med. Res., *19*, 1908, 182; Levine, Amer. Jour. Pub. Health, *7*, 1917, 785; Winslow, Kligler and Rothberg, Jour. Bact., *4*, 1919, 485; Bergey et al., Manual, 1st ed., 1923, 204; etc.

Bacillus cuniculicida Migula. (Bacillus der Kaninchenseptikämie, Eberth and Mandry, Arch. f. path. Anat., *121*, 1890; *Bacillus cuniculicida mobilis* Kruse, in Flügge, Die Mikroorganismen, 3 Aufl., *2*, 1896, 406; *Bacterium cuniculicida mobilis* Chester, Ann. Rept. Del. Col. Agr. Exp. Sta., *9*, 1897, 132; Migula, Syst. d. Bakt., *2*, 1900, 757; not *Bacillus cuniculicida* Flügge, Die Mikroorganismen, 2 Aufl., 1886, 251.) From peritoneal exudate of a rabbit.

Bacillus mustelaecida Trevisan. (Bacillus der Frettchenseuche, Eberth and Schimmelbusch, Fortschr. d. Med., *6*, 1888, 295; also see Arch. f. path. Anat., *115*, 1889, 282; Trevisan, I generi e le specie delle Batteriacee, 1889, 13; *Pasteurella mustelaecida* DeToni and Trevisan, in Saccardo, Sylloge Fungorum, *8*, 1889, 996; *Bacillus mustelae septicus* Kruse, in Flügge, Die Mikroorganismen, 3 Aufl., *2*, 1896, 405; *Bacterium mustelae septicus* Chester, Ann. Rept. Del. Col. Agr. Exp. Sta., *9*, 1897, 138; *Bacillus mustelae* Migula, Syst. d. Bakt., *2*, 1900, v and 756.) From a disease of ferrets.

Bacterium anatis Migula. (Bactéries du choléra des canards, Cornil and Toupet, Compt. rend. Acad. Sci. Paris, *106*, 1888, 1747; *Bacillus cholerae anatum* Kruse, in Flügge, Die Mikroorganismen, 3 Aufl., *2*, 1896, 417; Migula, Syst. d. Bakt., *2*, 1900, 364.) Regarded as the cause of duck cholera and very similar to, if not identical with, *Pasteurella avicida*. See Rettger and Scoville, Jour. Inf. Dis., *26*, 1920, 220. From the blood and other organs of infected ducks.

Bacterium cuniculi Migula. (Bacillus der Brustseuche des Kaninchens, Beck, Ztschr. f. Hyg., *15*, 1893, 363; *Bacillus cuniculi pneumonicus* Kruse, in Flügge, Die Mikroorganismen, 3 Aufl., *2*, 1896, 418; *Bacterium cuniculi pneumonicus* Chester, Ann. Rept. Del. Col. Agr. Exp. Sta., *9*, 1897, 84; Migula, Syst. d. Bakt., *2*, 1900, 370; *Bacterium beckii* Chester, Man. Determ. Bact., 1901, 142.) Associated with a lung plague of rabbits.

Bacterium haemorrhagicum (Kruse) Lehmann and Neumann. (Kolb, Arb. kaiserl. Gesundheitsamte, *7*, 1892, 60; *Bacillus haemorrhagicus* Kruse, in Flügge, Die Mikroorganismen, 3 Aufl., *2*, 1896, 424; Lehmann and Neumann, Bakt. Diag., 1 Aufl., *2*, 1896, 194.) From the mucous membranes of fever patients.

Bacterium palumbarium Migula. (La bactérie de la maladie des palombes, Leclainche, Ann. Inst. Past., *8*, 1894, 493; *Bacillus cholerae columbarum* Kruse, in Flügge, Die Mikroorganismen, 3 Aufl., *2*, 1896, 417; *Bacterium cholerae columbarum* Chester, Ann. Rept. Del. Col. Agr. Exp. Sta., *9*, 1897, 84; Migula, Syst. d. Bakt., *2*, 1900, 368; *Bacterium columbarum* Chester, Man. Determ. Bact., 1901, 141.) Associated with an epidemic in wild pigeons.

Bacterium phasianicida Klein. (Klein, Cent. f. Bakt., I Abt., Orig., *31*, 1902, 76; *Bacterium phasianidarum mobile* Enders, Berl. tierarztl. Wchnschr., No. 23, 1902; abst. in Cent. f. Bakt., I Abt., Ref., *34*, 1904, 384.) From an epidemic in pheasants (England). Hadley, Elkins and Caldwell (Rhode Island Agr. Exp. Sta., Bull. 174, 1918, 28) state that this species (which they call *B. phasianicida*) belongs in the group of paratyphoids (*Salmonella*).

Bacterium purpurum Chester. (Bacillus of purpura-haemorrhagica, Babes, Septiche Proz. Kindesalters, Leipzig. 1889; *Bacillus haemorrhagicus septicus*

Kruse, in Flügge, Die Mikroorganismen, 3 Aufl., *2*, 1896, 424; *Bacterium haemorrhagicus septicus* Chester, Ann. Rept. Del. Col. Agr. Exp. Sta., *9*, 1897, 85; Chester, Man. Determ. Bact., 1901, 143.) From a case of septicemia in man.

Bacterium tizzonii Migula. (Bacillus der haemorrhagischen Infektion, Tizzoni and Giovannini, in Zeigler, Beiträge, *7*, 1889, 300; *Bacillus haemorrhagicus velenosus* Kruse, in Flügge, Die Mikroorganismen, 3 Aufl., *2*, 1896, 425; *Bacterium haemorrhagicus velenosus* Chester, Ann. Rept. Del. Col. Agr. Exp. Sta., *9*, 1897, 85; Migula, Syst. d. Bakt., *2*, 1900, 386; *Bacterium velenosum* Chester, Man. Determ. Bact., 1901, 144.) From the blood of a child having a hemorrhagic infection.

Bacterium vassalei Migula. (Tizzoni and Giovannini, in Zeigler, Beiträge, *7*, 1889; *Bacillus haemorrhagicus nephritidis* Kruse, in Flügge, Die Mikroorganismen, 3 Aufl., *2*, 1896, 424; *Bacterium haemorrhagicus nephritidis* Chester, Ann. Rept. Del. Col. Agr. Exp. Sta., *9*, 1897, 85; Migula, Syst. d. Bakt., *2*, 1900, 387; *Bacterium nephritidis* Chester, Man. Determ. Bact., 1901, 145.) Isolated by Vassale from a case of hemorrhagic nephritis.

Pasteurella bouffardi Commes. (Commes, 1919; quoted from Neveu-Lemaire, Précis de Parasitol. Hum., 5th ed., 1921, 21.) The cause of a human pasteurellosis observed by Bouffard at Bamako in 1909.

Pasteurella caniseptica Hauduroy et al. (Pasteurella du chien, Lignières, Recueil de Méd. Vét., *77*, 1900, 469; *Bacterium canicida* Lehmann and Neumann, Bakt. Diag., 4 Aufl., *2*, 1907, 277; Hauduroy et al., Dict. d. Bact. Path., 1937, 312.) From dogs.

Pasteurella capriseptica (Lanfranchi and Pacchioni) Hauduroy et al. (*Bacillus pneumoniae caprae* Nicolle and Refik-Bey, Ann. Inst. Past., *10*, 1896, 321; Pasteurella du chevre, Lignières, Recueil de Méd. Vétér., *77*, 1900, 536; *Bacillus caprisepticus* Lanfranchi and Pacchioni, 1926; *Bacillus bipolaris capristepticus* Chefik Kolayi and Raif, 1935; Hauduroy et al., Dict. d. Bact. Path., 1937, 313.) From hemorrhagic septicemia in goats.

Pasteurella caviae Hauduroy et al. (Gaté and Billa, Compt. rend. Soc. Biol., Paris, *99*, 1928, 814; Hauduroy et al., Dict. d. Bact. Path., 1937, 313.) From a guinea pig with a tuberculosis-like disease.

Pasteurella caviseptica (Schwer) Hauduroy et al. (Pasteurella du cobaye, Phisalix, Compt. rend. Soc. Biol., Paris, *1*, 1898, 761; *Bacterium cavisepticum* Schwer, Cent. f. Bakt., I Abt., Orig., *33*, 1902, 47; Hauduroy et al., Dict. d. Bact. Path., 1937, 314.) From hemorrhagic septicemia in guinea pigs.

Pasteurella desmodilli Pirie. (Pub. So. African Inst. Med. Res., *4*, 1929, 191.)

Pasteurella equiseptica Kelser. (Bacille de la septicémie hémorragique du cheval, Lignières, Bull. Soc. Centr. d. Méd. Vét., *15*, 1897, 437 and *16*, 1898, 849; La Pasteurella equine, Lignières, Recueil de Méd. Vét., *77*, 1900, 524; Kelser, Man. Vet. Bact., 1st ed., 1927, 191; *Bacillus equisepticus* Kelser, *ibid.*; *Bacillus pneumoniae equi* Poels.) From horses.

Pasteurella felis (Migula) Hauduroy et al. (*Bacillus salivarius septicus felis* Fiocca, Ann. d. Instit. d'igiene d. Univ. di Roma, *2*, 1892 and Cent. f. Bakt., *11*, 1892, 406; *Bacillus felis septicus* Kruse, in Flügge, Die Mikroorganismen, 3 Aufl., *2*, 1896, 423; *Bacterium felis septicus* Chester, Ann. Rept. Del. Col. Agr. Exp. Sta., *9*, 1897, 81; Pasteurella du chat, Lignières, Recueil de Méd. Vét., *77*, 1900, 493; *Bacterium felis* Migula, Syst. d. Bakt., *2*, 1900, 375; Hauduroy et al., Dict. d. Bact. Path., 1937, 316.) From the sputum of a cat.

Pasteurella mastidis (Miessner and Schoop) Hauduroy et al. (Stäbchenbakterium, Dammann and Freese, Deut. tierärztl. Wchnschr., *15*, 1907, 165; Bipolar organism of the Pasteurella group, Leyshon, Vet. Jour., *85*, 1929, 299; *Bacterium mastitidis* Miessner and Schoop, Deut. tierärztl. Wchnschr., *40*,

1932, 69; Pasteurella, Marsh, Jour. Amer. Vet. Med. Assoc., *81* (N.S. *34*), 1932, 376; *Bacterium ovinum* Haupt, Cent. f. Bakt., I Abt., Orig., *123*, 1932, 365; Hauduroy et al., Dict. d. Bact. Path., 1937, 316.) The cause of infectious mastitis of ewes.

Pasteurella necrophora Hauduroy et al. (Bacille de la nécrose infectieuse des Canaris, Cornell, The Vet. Record, *84*, 1928, 350; Hauduroy et al., Dict. d. Bact. Path., 1937, 318.) From domestic canaries.

Pasteurella oviseptica Hauduroy et al (Galtier, Jour. d. méd. vét. et d. zoot., 1889–1890, 58, 113 and 481; La Pasteurella ovine, Lignières, Recueil de Méd. Vétér., 77, 1900, 529; *Bacillus bipolaris ovisepticus* Hutyra, in Kolle and Wassermann, Hand. d. path. Mikroorg., 2 Aufl., *6*, 1913, 67; Hauduroy et al., Dict. d. Bact. Path., 1937, 319.) From sheep.

Pasteurella pericarditis Hauduroy et al. (*Bacterium cavarum pericarditis* Roth, Acta Pathol. et Microb. Scand., *11*, 1934, 335; Hauduroy et al., Dict. d. Bact. Path., 1937, 319.) From guinea pigs.

Pasteurella strasburgensis Hauduroy et al. (Coccobacille de Strasbourg, Debre, Compt. rend. Soc. Biol., Paris, *82*, 1919, 224; Hauduroy et al., Dict. d. Bact. Path., 1937, 323.) From a case of purulent pleurisy.

Pfeifferella anatipestifer Hendrickson and Hilbert. (Hendrickson and Hilbert, The Cornell Veterinarian, *22*, 1932, 239; *Hemophilus anatipestifer* Hauduroy et al., Dict. d. Bact. Path., 1937, 247.) From a septicemic disease of ducks.

Genus II. Malleomyces *Pribram.**

(*Cladascus* Enderlein (in part), Sitzber. Gesell. Naturf. Freunde, Berlin, 1917, 316; *Pfeifferella* Buchanan, Jour. Bact., *3*, 1918, 54; Pribram, Klassification der Schizomyceten, Leipzig, 1933, 11 and 93; *Loefflerella* Gay et al., Agents of Disease and Host Resistance, Indianapolis, 1935, 782.) From Latin *malleus*, glanders and *myces*, fungus.

Because *Pfeifferella* was proposed inadvertently (Buchanan, Gen. Syst. Bact., 1925, 420) and because of a general feeling that it is inappropriate, *Malleomyces* Pribram is used as the earliest suitable name for this genus. The indefinite description of an organism (*Malleomyces equestris*) by Hallier (Ztschr. f. Parasitenkunde, 1870, 119) as the cause of glanders has not previously caused confusion and need not do so in the future.

Short rods, with rounded ends, sometimes forming threads and showing a tendency toward branching. Motile or non-motile. Gram-negative. Tendency to bipolar staining. Milk slowly coagulated. Gelatin may be liquefied. Specialized for parasitic life. Grow well on blood serum and other body fluid media.

The type species is *Malleomyces mallei* (Flügge) Pribram.

Key to the species of genus Malleomyces.

I. Carbohydrates not fermented. Honey-like colonies on potato. Glycerol agar colonies slimy or tenacious, translucent. Non-motile.
   1. *Malleomyces mallei.*

II. Carbohydrates fermented. Profuse, creamy growth on potato. Glycerol agar colonies iridescent, becoming corrugated. Motile.
   2. *Malleomyces pseudomallei.*

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* Revised by Prof. Robert S. Breed, New York State Experiment Station, Geneva, New York, December, 1938; further revision, December, 1945.

1. **Malleomyces mallei** (Zopf) Pribram. (Rotzpilz, Löffler and Schütz, Deutsche med. Wchnschr., No. 52, 1882; *Bacillus mallei* Zopf, Die Spaltpilze, 3 Aufl., 1885, 89; Rotzbacillus, Löffler, Arb. kaiserl. Gesundheitsamte, *1*, 1886, 222; *Bacterium mallei* Migula, in Engler and Prantl, Die natürl. Pflanzenfam., *1*, 1a, 1895, 21; *Corynebacterium mallei* Lehmann and Neumann, Bakt. Diag., 2 Aufl., *2*, 1899, 366; *Mycobacterium mallei* Chester, Man. Determ. Bact., 1901, 353; *Cladascus mallei* Enderlein, Sitzber. Gesell. Naturf. Freunde Berlin, 1917, 395; *Pfeifferella mallei* Buchanan, Jour. Bact., *3*, 1918, 54; *Sclerothrix mallei* Vuillemin, Encyclopédie Mycolog., Paris, *2*, Champignons Parasites, 1931, 135; *Brucella mallei* Pacheco, Revista da Sociedado paulista de Medicina veterinaria, *3*, 1933, 1; *Actinobacillus mallei* Thompson, Jour. Bact., *26*, 1933, 226; also Jour. Bact., *25*, 1933, 44; Pribram, Klassification der Schizomyceten. Leipzig and Vienna, 1933, 93; *Loefflerella mallei* Gay et al., Agents of Disease and Host Resistance, Indianapolis, 1935, 782.) From Latin *malleus*, glanders, a disease of horses.

Bacillus ozenae Trevisan (Corr. Ser., 1884, n. 222) is identical with this species according to Trevisan (I generi e le specie delle Batteriacee, 1889, 13).

Description largely from Kelser, Man. Vet. Bact., 2nd ed., 1933, 325.

Slender rods: 0.5 to 1.0 by 2.0 to 5.0 microns, with rounded ends, usually occurring singly, in pairs and in groups, but may grow into filaments. Branching involution forms on glycerol agar. Show irregular staining. Bipolar staining common. Non-motile. Gram-negative.

Gelatin: Poor growth. Usually no liquefaction. May be slowly liquefied (Jordan, General Bact., 11th ed., 1935, 491).

Agar colonies: Moist, grayish-white layer, translucent, ropy, with regular borders. Later become yellowish or yellowish-brown.

Agar slants: Glistening, moist, ropy, grayish-white growth.

Löffler's serum: Good growth. Moist, viscid, yellowish colonies develop after 36 to 48 hours.

Broth: Turbid, sometimes with thin pellicle. Slimy or ropy sediment.

Litmus milk: Coagulation usually occurs after a week with some acid production. Litmus may or may not be reduced.

Potato: After 36 to 48 hours, pale yellow, honey-drop-like colonies. Later becoming darker, reddish-yellow or chocolate color. The medium sometimes has a faint greenish tinge around the growth.

Indole not formed.

Nitrites not produced from nitrates.

Carbohydrates usually not fermented. Some strains produce small amounts of acid from glucose.

Optimum temperature 37°C. No growth below 20°C or above 44°C.

Aerobic, facultative anaerobic.

Common name: Glanders bacillus.

Distinctive characters: Culture media of slightly acid reaction best suited for growth; addition of glycerol favors growth; honey-like growth on potato.

Source: Isolated by Löffler and Schütz from the liver and spleen of a horse. Lesions in animals and man.

Habitat: The cause of glanders, affecting horses, man, sheep and goats. Transmissible to dogs, cats, rabbits and guinea pigs.

2. **Malleomyces pseudomallei** (Whitmore) Breed. (*Bacillus pseudomallei* Whitmore, Jour. Hyg., *13*, 1913, 1; *Bacillus whitmori* Stanton and Fletcher, Trans. 4th Cong. Far East Assn. Trop. Med., *2*, 1921, 196; also Jour. Hyg., *23*, 1925, 347; *Pfeifferella pseudomallei* Ford, Textb. of Bact., 1927, 294; *Flavobacterium pseudomallei* Bergey et al., Manual, 3rd ed., 1930, 146; *Sclerothrix whitmori* Vuillemin, Encyclopédie Mycolog., *2*, Champignons Parasites, 1931, 136; *Actinobacillus pseudomallei* Thompson, Jour. Bact., *26*, 1933, 226; also Jour. Bact.,

25, 1933, 44; *Loefflerella whitmori* Gay et al., Agents of Disease and Host Resistance, Indianapolis, 1935, 791; Breed, in Manual, 5th ed., 1939, 300.) Latinized, false glanders.

Short rods: With rounded ends, occurring singly and in short chains, showing bipolar staining. Motile. Gram-negative.

Gelatin stab: Moderate, crateriform liquefaction.

Agar colonies: Circular, slightly raised, thick, opaque, cream-colored with irregular margin.

Glycerol agar slant: Wrinkled, thick, rugose, cream-colored growth.

Broth: Turbid with pellicle.

Litmus milk: Curdling with slowly developed acidity, pink sediment; may be digested.

Potato: Vigorous, cream-colored growth.

Indole not formed.

Acid from glucose, maltose, lactose, sucrose and mannitol.

Blood serum slowly liquefied.

Aerobic, facultative.

Optimum temperature 37°C.

Source: Lesions and blood in rats, guinea pigs, rabbits and man. Once from a transient nasal discharge in a horse (Stanton, Fletcher and Symonds) and once from a splenic abscess in a cow (Nicholls).

Habitat: Glanders-like infection (melioidosis) in rats, guinea pigs, rabbits and in man in India, Federated Malay States and Indo-China.

Appendix: The following may belong in this genus:

Flavobacterium orchitidis Sherwood, Irwin and Marts. (Sherwood, Irwin (not Edwin) and Marts, Amer. Jour. Diseases of Children, *45*, 1933, 446; Sherwood, Jour. Kansas Med. Soc., *34*, 1933, 220.) From a case of meningitis. Sherwood (personal communication, 1945) now considers this organism identical with *Bacillus whitmori* (*Malleomyces pseudomallei*). See Manual, 5th ed., 1939, 538 for a description of this species.

Malleomyces agliaceus Pribram. (Bacillo opale agliaceo, Vincenzi, Giorn. d. R. Accad. d. Med. Torino, 1890, No. 6; Pribram, Klassification der Schizomyceten, Leipzig, 1933, 93.) Cause of pseudotuberculosis in frogs.

Genus III. Actinobacillus *Brumpt.**

(Précis de Parasitologie, Paris, 1st ed., 1910, 849.)

Medium-sized, aerobic, Gram-negative rods which frequently show much pleomorphism. Coccus-like forms frequent. Tendency to bipolar staining. Acid but no gas produced from carbohydrates. Grow best, especially when freshly isolated, under increased CO_2 tension. Pathogenic for animals; some species attack man. The outstanding characteristic of the group is the tendency to form aggregates in tissues or culture which resemble the so-called sulfur granules of actinomycosis.

The type species is *Actinobacillus lignieresi* Brumpt.

1. **Actinobacillus lignieresi** Brumpt. (Actinobacilo, Lignières and Spitz, Boletin d. Agri. y Ganaderia, Buenos Aires, *11*, 1902, 169; *Actinobacillus*, Lignières and Spitz, Cent. f. Bakt., I Abt., Orig., *35*, 1903, 294; Brumpt, Précis de Parasitol., Paris, 1st ed., 1910, 849; *Bacillus lignieri* (sic) Macé, Traité de Bactériolo-

*** Revised by Prof. W. A. Hagan, New York State Veterinary College, Ithaca, New York, December, 1938; further revision, December, 1945.**

gie, 6th ed., *2*, 1913, 743; *Nocardia lignieresi* Chalmers and Christopherson, Ann. Trop. Med. and Parasit., *10*, 1916, 242; *Discomyces lignieresi* Brumpt, Précis de Parasitol., Paris, 3rd ed., 1922, 993; *Pasteurella lignieresi* Vuillemin, Encyclopédie Mycologique, Paris, *2*, Champignons Parasites, 1931, 136.) Named for Lignières, who first worked with this organism.

Bacterium purifaciens Christiansen (Maanedsskr. f. Drylaeger, *29*, 1917, 449; *Pasteurella purifaciens* Hauduroy et al., Dict. d. Bact. Path., 1937, 322) is regarded as identical with this organism by Tunnicliff (Jour. Inf. Dis., *69*, 1941, 52).

Rods: 0.4 by 1.0 to 15.0 microns. Cocco-bacillary forms frequent. Non-motile. Gram-negative.

Gelatin: Growth sparse or fails. No liquefaction.

Agar: Primary cultures usually succeed best when the inoculum is introduced by stab. Serum agar is more favorable than plain. Surface colonies are small, bluish, translucent at first, later becoming opaque.

Broth: Serum favors growth. Freshly isolated strains usually grow in form of small granules which adhere to sides of tube, leaving broth fairly clear. Later most strains grow diffusely, often forming a fragile pellicle.

Litmus milk: Most strains cause no change. Sometimes slight acid. No coagulation.

Potato: Little or no growth.

Acid but no gas within 48 hours from glucose, fructose, galactose, maltose, sucrose and mannitol. Acid after longer incubation from lactose, raffinose and glycerol.

Indole is formed in small amounts.

Nitrites not produced from nitrates.

Aerobic. Is favored by increased CO_2 tension. Will not grow anaerobically.

Optimum temperature 37°C.

Pathogenic for cattle and swine. A few cases reported in man. Rabbits and guinea pigs slightly susceptible to inoculation.

Source and habitat: Usually isolated from the lesions of actinobacillosis of cattle. This condition is often clinically diagnosed as actinomycosis. Lesions found in soft tissues, usually lymph nodes, where granulomatous tumors are formed. Eventually these break down to form abscesses.

2. **Actinobacillus actinomycetemcomitans** Topley and Wilson. (*Bacterium actinomycetem comitans* Klinger, Cent. f. Bakt., I Abt., Orig., 1912, 198; *Actinobacillus actinomycetem comitans* Topley and Wilson, Princip. of Bact. and Immun., *1*, 1931, 256; Topley and Wilson, *ibid.*, 2nd ed., 1936, 279.) From actinomycete, and Latin *comitans*, accompanying.

Description taken from Topley and Wilson (*loc. cit.*), Colebrook (Brit. Jour. Exp. Path., *1*, 1920, 197), and Bayne-Jones (Jour. Bact., *10*, 1925, 572).

Cocco-bacilli: Rods 1.0 to 1.5 microns long, cocci 0.6 to 0.8 micron in diameter. Occurring in densely-packed masses. Non-motile. Gram-negative.

Gelatin: No liquefaction.

Agar colonies: Small, tough, adherent.

Glucose agar: Growth thin, dry, granular, hard, slightly yellow, adherent.

Liquid gelatin or broth: At 37°C, numerous isolated, translucent granules, 0.5 to 1.0 mm in diameter, form along sides of tube. In a few days they fuse into a grayish-white mass, forming ring around tube and pellicle over surface. Later granules become opaque, grayish-white.

Glucose broth: Turbid. Yellowish flakes.

Milk: No growth.

Potato: No growth.

Acid but no gas from glucose and lactose.

Not pathogenic for laboratory animals.

No growth at 20°C.

Aerobic, facultative.

Distinctive character: Manner of growth in liquid gelatin.

Source: Found in lesions of actinomycosis.

Habitat: Presumably in actinomycotic lesions.

3. **Actinobacillus actinoides** (Smith) Topley and Wilson. (*Bacillus actinoides* Th. Smith, Jour. Exp. Med., *28*, 1918, 333; *Actinomyces actinoides* Bergey et al., Manual, 1st ed., 1923, 346; Topley and Wilson, Princip. of Bact. and Immun., 1st ed., *1*, 1931, 256.) From Greek, ray-like.

Slender rods in tissues. In cultures may be bacillary or coccoid in form. Grows only under increased CO_2 tension (so-called microaerophilic). Does not grow on ordinary agar or broth, except occasionally when transferred from more favorable media. Most characteristic growth on coagulated blood serum.

Gelatin: No growth.

Agar colonies: Very minute, pale, straw color.

Agar slant: Best growth seen in water of condensation. Serial transfers on this medium generally fail.

Broth: No growth.

Litmus milk: No growth.

Potato: No growth.

Coagulated blood serum (cow): Growth appears first in the condensation water. Appear as granules, consisting of capsular material in which bacillary forms are embedded. Surface mulberry-like because of club-like extensions of capsular material. In stained preparations, the capsular material appears amorphous.

Optimum temperature 37°C.

Microaerophilic.

Not pathogenic for laboratory animals, except possibly the white rat in which a spontaneous chronic pneumonia occurs caused by an organism indistinguishable from this one. Experiments with rats by artificial inoculation have not been reported.

Source: From lungs of calves suffering from chronic pneumonia.

Habitat: Has not been recognized in nature except in pathological processes.

* APPENDIX TO TRIBE PASTEURELLEAE.

While the authors who describe the following new genus with its single species do not indicate its general relationships, it would appear to be as closely related to the species placed in *Parvobacteriaceae* as to those in any other family. It is therefore placed in this appendix pending a clarification of the situation.

Genus A. **Donovania** *Anderson, De Monbreun and Goodpasture.*

(Jour. Exp. Med., *81*, 1945, 25.) Named for C. Donovan who first described the type species.

Pleomorphic non-motile rods, exhibiting single or bipolar condensations of chromatin. Occur singly and in clusters. May be capsulated or non-capsulated. Gram-negative. Growth outside human body occurs only in the yolk, yolk sac or amniotic fluid of developing chick embryo or in a medium containing embryonic yolk. Pathogenic for man causing granulomatous lesions, particularly in the inguinal region.

The type species is *Donovania granulomatis* Anderson, De Monbreun and Goodpasture.

1. **Donovania granulomatis** Anderson et al. (Epithelial cell parasites, Donovan, Indian Med. Gaz., *40*, 1905, 414; Donovan bodies, Dienst, Greenblatt and Sanderson, Jour. Inf. Dis., *62*, 1938, 112; Donovan organism, Anderson, Science, *97*, 1943, 560; Anderson, De Monbreun and Goodpasture, Jour. Exp. Med., *81*, 1945, 25.) From M. L. *granuloma*, of granuloma.

Pleomorphic rods 1 to 2 microns in length, with rounded ends, occurring singly and in clusters. Intracellular forms usually capsulated. Non-motile. Gram-negative.

No growth on ordinary culture media.

Chick embryo: Grows readily in yolk, yolk sac and feebly in amniotic fluid of developing chick embryo.

Embryonic yolk medium: Growth occurs.

Distinctive characters: Capsulated forms readily demonstrated by means of Wright's stain as blue bacillary bodies surrounded by well-defined dense pinkish capsules. Non-capsulated forms variable in morphology. Characteristic safety-pin forms may be demonstrated.

Not pathogenic for the common experimental animals.

Source: Granulomatous lesions of man.

Habitat: Human lesions. The cause of granuloma inguinale.

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* Prepared by Dr. Orren D. Chapman, Syracuse Medical College, Syracuse, New York, March, 1946.

TRIBE II. BRUCELLEAE BERGEY, BREED AND MURRAY.

(Preprint, Manual, 5th ed., October, 1938, vi.)

Small, motile or non-motile rods or coccoids which grow on special media. There is a single genus *Brucella*.

Genus I. Brucella *Meyer and Shaw.**

(Jour. Inf. Dis., *27*, 1920, 173.) Named for Sir David Bruce, who first recognized the organism causing undulant fever.

Short rods with many coccoid cells, 0.5 by 0.5 to 2.0 microns; non-motile; capsulated; Gram-negative; gelatin not liquefied; neither acid nor gas from carbohydrates; urea utilized; parasitic, invading all animal tissues, producing infection of the genital organs, the mammary gland, the respiratory and intestinal tracts; pathogenic for various species of domestic animals and man.

The type species is *Brucella melitensis* (Hughes) Meyer and Shaw.

Key to the species of genus **Brucella.**

I. Non-motile.
 A. Grow in special media containing basic fuchsin.
  1. Grows in media containing thionin.
   1. *Brucella melitensis.*
  2. Does not grow in media containing thionin.
   2. *Brucella abortus.*
 B. Does not grow in media containing basic fuchsin.
  1. Grows in media containing thionin.
   3. *Brucella suis.*

II. Motile.
   4. *Brucella bronchiseptica.*

Differential characters of the three closely related species of genus *Brucella*.

Species	Infectivity for guinea pigs	Requires CO_2 for isolation	H_2S formation	*Glucose utilized	Amino-nitrogen utilized	Growth in the presence of	
						Thionin	Basic fuchsin
		10 per cent	*days*				
Brucella melitensis	++	0	±1	+++	+	+++	+++
Brucella abortus	++	++	2	+	++	0	+++
Brucella suis	++	0	4	+++	+	+++	0

* All utilize glucose in shake cultures.

1. **Brucella melitensis** (Hughes) Meyer and Shaw. (Bruce, Practitioner, *39*, 1887, 161; *ibid.*, *40*, 1888, 241; Rept. Army Med. Dept., London, *32*, 1890, Append. No. 4, 465; *streptococcus Miletensis* (sic) Hughes, The Mediterranean Naturalist, *2*, February 1, 1892, 325; *Micrococcus melitensis* Bruce, Ann. Inst.

* Revised by Prof. I. F. Huddleson, Michigan State College, East Lansing, Michigan, December, 1942.

Past., *7*, April, 1893, 289; Hughes, La Riforma Med., *3*, Aug. or Sept., 1893, 789 and Ann. Inst. Past., *7*, Aug., 1893, 630; *Bacterium melitense* Saisawa, Ztschr. f. Hyg., *70*, 1912, 181; Meyer and Shaw, Jour. Inf. Dis., *27*, 1920, 173; *Bacillus melitensis* Holland, Jour. Bact., *5*, 1920, 219; *Alcaligenes melitensis* Bergey et al., Manual, 1st ed., 1923, 235; *Brucella melitensis* var. *melitensis* Evans, U. S. Public Health Reports, *38*, 1923, 1947.) From Latin, of Malta.

Short ellipsoidal rods: 0.3 to 0.4 micron in length, occurring singly and in pairs, rarely in short chains. Non-motile. Non-acid-fast. Gram-negative.

Gelatin colonies: Small, clear, entire.

Gelatin stab: Slow growth. No liquefaction.

Agar colonies: Small, circular, convex, amorphous, smooth, glistening, entire, bluish-green, grayish if R type.

Agar slant: Growth slow, moist, honey-like, entire. After a week, the agar is turned brownish and crystals may appear.

Broth: After 10 days, moderate turbidity and grayish sediment. Reaction alkaline, pH 8.0 or higher.

Litmus milk: Unchanged at 24 hours. Later becomes alkaline.

Potato: Scant growth, grayish becoming brownish.

Indole not formed.

Nitrates reduced, often with complete disappearance of nitrite (Zobell and Meyer, Jour. Inf. Dis., *51*, 1932, 99). Because of the latter fact, reports in the literature are apparently contradictory.

Ammonia produced from urea.

Growth enhanced on beef liver or tryptose agar of pH 6.8.

Neither acid nor gas from carbohydrate media.

Optimum reaction pH 7.4.

Optimum temperature 37°C. No growth at 6° or at 45°C. Killed at 59°C.

Aerobic.

Distinctive characters: Requires no increased CO_2 tension.

Source: Isolated by Bruce (1887, *loc. cit.*) from the spleen in fatal cases of Malta fever.

Habitat: Chief host the milch goat. The cause of undulant fever (brucellosis) in man and abortion in goats. May infect cows and hogs and be excreted in their milk. Infectious for all domestic animals.

2. **Brucella abortus** (Schmidt and Weis) Meyer and Shaw. (Bacillus of abortion, Bang, Ztschr. f. Thiermed., *1*, 1897, 241; *Bacterium abortus* Schmidt and Weis, Bakterierne, 1901, 266; *Bacterium abortivum* Chester, Man. Determ. Bact., 1901, 121; *Corynebacterium abortus endemici* Preisz, Cent. f. Bakt., I Abt., Orig., *33*, 1902, 194; *Bacillus abortus* Evans, Jour. Wash. Acad. Sci., *5*, 1915, 122; Meyer and Shaw, Jour. Inf. Dis., *27*, 1920, 173; *Alcaligenes abortus* Bergey et al., Manual, 1st ed., 1923, 234; *Brucella melitensis* var. *abortus* Evans, Public Health Reports, *38*, 1923, 1947.) From Latin *abortus*, an untimely birth.

The morphological and cultural characters are similar to those of *Brucella melitensis* with the following exceptions: Requires 10 per cent CO_2 for isolation, becomes aerobic after several transfers; the browning of the medium in agar slant culture is less marked; S cultures can be differentiated from *Brucella melitensis*, but not from *Brucella suis*, by the agglutinin absorption test.

Source: From the genital organs and milk of infected cattle and from blood in human cases of undulant fever.

Habitat: Chief host the milch cow. The cause of infectious abortion in cattle. The same effects are produced in mares, sheep, rabbits and guinea pigs, and all domestic animals except hogs. Causes undulant fever (brucellosis) in man.

3. **Brucella suis** Huddleson. (Organism resembling *Bacillus abortus*, Anonymous, U. S. D. A. Ann. Rept. Secy. Dept., Rept. of Chief Bur. Animal Ind.,

1914, 86 (30); authorship established by Traum in North Amer. Vet., *1*, No. 2, 1920; described as *Bacillus abortus* by Good and Smith, Jour. Bact., *1*, 1916, 415; Huddleson, Undulant Fever Symposium, Amer. Pub. Health Assoc., (Oct., 1928) 1929, 24; also Mich. Agr. Exp. Sta. Tech. Bull. 100, 1929, 12; *Brucella melitensis* var. *suis* Hardy, Jordan, Borts and Hardy, Public Health Reports, *45*, 1930, 2433; *Bacillus abortus suis* Meyer, Amer. Jour. Pub. Health, *21*, 1931, 503.) From Latin, of swine.

The morphological and cultural characters are similar to those of *Brucella melitensis*.

S cultures of *Brucella suis* can be differentiated from S cultures of *Brucella melitensis*, but not from S cultures of *Brucella abortus*, by the agglutinin absorption test.

Source: From urinogenital and many other organs of swine.

Habitat: Chief host the hog. Causes abortion in swine and undulant fever (brucellosis) in man. Also infectious for horses, dogs, cows, monkeys and laboratory animals.

The differentiation of the above species of *Brucella* by the bacteriostatic action of dyes depends upon the medium used. When tryptose agar (Difco) is used, basic fuchsin and thionin should be used in a final dilution of 1:100,000.

There are several forms of the R and mucoid phases of *Brucella spp.* (Huddleson, Amer. Jour. Vet. Res., 7, 1946, 5). The true R type differs from the S type in its lack of pathogenicity, its antigenic properties, its susceptibility to agglutination by exposure of suspensions to heat and to basic dyes in concentration of 1:2000, and colonial appearance. The mucoid phases differ antigenically, morphologically and culturally. Colonies on agar are spherical or flat, regular in contour, grayish to mucoid in appearance. Suspensions are not agglutinated by heat or dyes, or always by special agglutinating serums. There is no change in their growth characteristics on media containing either basic fuchsin or thionin.

4. **Brucella bronchiseptica** (Ferry) Topley and Wilson. (Ferry, Amer. Vet. Rev., *37*, 1910, 499; also see McGowan, Jour. Path., *15*, 1911, 372; *Bacillus bronchicanis* Ferry, Jour. Inf. Dis., *8*, 1911, 402; *Bacillus bronchisepticus* Ferry, Amer. Vet. Rev., *41*, 1912, 79; *Bacterium bronchisepticus* Evans, Jour. Inf. Dis., *18*, 1916, 578; *Bacterium bronchicanis* Holland, Jour. Bact., *5*, 1920, 221; *Alcaligenes bronchisepticus* Bergey et al., Manual, 1st ed., 1923, 234; Topley and Wilson, Princip. Bact. and Immun., 1st ed., *1*, 1931, 508.) Latinized, disease of the bronchial tubes.

Evans (*loc. cit.*, 593) regards *Bacterium bronchisepticus* as related to *Bacterium abortus* morphologically, culturally, biochemically and serologically.

Short slender rods: 0.4 to 0.5 by 2.0 microns, usually occurring singly, sometimes in pairs and chains. Motile with 4 to 6 peritrichous flagella (Topley and Wilson). Gram-negative.

Gelatin colonies: Similar to those on agar.

Gelatin stab: Slow filiform growth. No liquefaction.

Agar colonies: Small, opaque, white, slightly raised, porcellaneous, entire.

Agar slant: Growth moderate but more luxuriant than in *Brucella melitensis*, filiform, slightly raised, smooth, opalescent, lustrous, moist, entire.

Broth: Turbid, with thin, gray pellicle and ropy sediment. Musty odor develops.

Litmus milk: Alkaline. No coagulation.

Potato: Growth fairly abundant, brownish, glistening, moist, sticky. Medium is darkened.

Indole not formed.

Nitrites often produced from nitrates (Topley and Wilson).

No acid or gas from glucose, sucrose, lactose, maltose or mannitol.

No H_2S produced (Topley and Wilson).

Catalase positive (Topley and Wilson).

Ammonia formed from urea and asparagine.

Optimum temperature 37°C. Killed in twenty minutes at 55°C.

Aerobic, facultative.

Source: From dogs affected with distemper.

Habitat: Causes acute, often fatal, pneumonia in dogs generally as a secondary invader in distemper. Also pathogenic for cats, rabbits, guinea pigs, ferrets, white rats and monkeys. Sometimes occurs in man.

Appendix: The following are recorded in the literature discussing this genus:

Brucella evansi Pacheco (Revista da Sociedade Paulista de Med. Vet., *3*, 1933, 9) is a name applied to a group of thirteen cultures referred to by Evans (Jour. Inf. Dis., *23*, 1918, 354) as abortus-like bacteria although she definitely indicates that these cultures do not agree with each other in their biochemical characteristics (*loc. cit.*, Table 4, p. 361).

The binomials *Brucella paramelitensis*, *Brucella paraabortus* and *Brucella parasuis* have been used for inagglutinable strains of these three species which are, according to Topley and Wilson (Princip. Bact. and Immun., 2nd ed., 1936, 632), now known to be merely rough variants, not deserving to be so named.

Micrococcus paramelitensis Negré and Raymond. (Compt. rend. Soc. Biol., Paris, *72*, 1912, 791 and 1052.)

Micrococcus pseudomelitensis Sergent and Zammitt, 1908. Exact reference not known.

TRIBE III. BACTEROIDEAE TRIB. NOV.

Motile or non-motile rods without endospores. May or may not require enriched culture media. Obligate anaerobes. Gram-negative.

Key to the genera of tribe **Bacteroideae.**

I. Cells with rounded ends.

Genus I. *Bacteroides*, p. 564.

II. Cells with pointed ends.

Genus II. *Fusobacterium*, p. 581.

Genus I. **Bacteroides** *Castellani and Chalmers.**

(Man. Trop. Med., 3rd ed., 1919, 959.)

Characters as for the tribe. From Greek, like a rod.

The type species is *Bacteroides fragilis* (Veillon and Zuber) Castellani and Chalmers.

NOTE: The descriptions have been taken largely from Weinberg et al. (Les Microbes Anaérobies, Paris, 1937, 658); Prévot (Ann. Inst. Past., *60*, 1938, 285); Hauduroy, Ehringer, Urbain, Guillot and Magrou (Dict. Bact. Path., Paris, 1937, 51); and Eggerth and Gagnon (Jour. Bact., *25*, 1933, 389). Because cultures of many of these organisms have not been subjected to critical study with identical tests and media, it is difficult to know how many should be considered as distinct species, and the present arrangement must be considered as tentative. The key, of necessity, has been drawn up from recorded characters which appeared useful for the purpose and these on further study may prove to be inadequate.

Key to the species of genus **Bacteroides.**

I. Not requiring enriched media.
  A. Gas formed from proteins.
    1. Hydrogen sulfide not produced.
      a. Non-motile.
        1. *Bacteroides fragilis.*
      aa. Motile.
        2. *Bacteroides serpens.*
    2. Hydrogen sulfide produced.
      a. Indole not formed.
        b. Very pleomorphic.
          3. *Bacteroides funduliformis.*
        bb. Not markedly pleomorphic.
          4. *Bacteroides siccus.*
      aa. Indole formed.
        b. Gelatin liquefied.
          5. *Bacteroides coagulans.*

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* Completely revised by Dr. T. E. Roy, Bacteriologist to the Hospital for Sick Children, Toronto, Ontario, Canada and Dr. C. D. Kelly, Assistant Professor of Bacteriology, McGill University, Montreal, P. Q., Canada, December, 1938; rearranged, December, 1945.

bb. Gelatin not liquefied.
c. No acid from lactose and maltose.
6. *Bacteroides varius.*
cc. Acid from lactose and maltose.
d. Acid from sucrose. No acid from glycerol.
7. *Bacteroides inaequalis.*
dd. No acid from sucrose. Acid from glycerol.
8. *Bacteroides insolitus.*

B. No gas formed from proteins.
1. Indole not formed.
a. Hydrogen sulfide not formed.
b. No acid from lactose.
9. *Bacteroides vescus.*
bb. Acid from lactose.
c. No acid from salicin.
10. *Bacteroides exiguus.*
cc. Acid from salicin.
11. *Bacteroides uncatus.*
aa. Hydrogen sulfide formed.
b. No acid from salicin. Acid from arabinose.
c. Gelatin liquefied.
12. *Bacteroides vulgatus.*
cc. Gelatin not liquefied.
13. *Bacteroides incommunis.*
bb. Acid from salicin. No acid from arabinose.
14. *Bacteroides distasonis.*
bbb. No acid from salicin or arabinose.
c. Acid from sorbitol.
15. *Bacteroides tumidus.*
cc. No acid from sorbitol.
16. *Bacteroides convexus.*
2. Indole formed.
a. No acid from salicin or arabinose.
17. *Bacteroides ovatus.*
aa. Acid from salicin and arabinose.
b. No acid from mannitol.
c. No acid from rhamnose.
18. *Bacteroides uniformis.*
cc. Acid from rhamnose.
d. Not capsu ated.
19. *Bacteroides thetaiotaomicron.*
dd. Capsulated.
20. *Bacteroides variabilis.*
bb. Acid from mannitol.
21. *Bacteroides gulosus.*

II. Requiring an enriched medium.
A. Producing a black pigment.
22. *Bacteroides melaninogenicus.*
B. Not producing pigment.
23. *Bacteroides caviae.*

1. **Bacteroides fragilis** (Veillon and Zuber) Castellani and Chalmers. (*Bacillus fragilis* Veillon and Zuber, Arch. Méd. Exp. et Anat. Path., *10*, 1898, 870; Castellani and Chalmers, Man. Trop. Med., 3rd ed., 1919, 959; *Fusiformis fragilis* Topley and Wilson, Princip. Bact. and Immun., 1st ed., *1*, 1931, 302; *Ristella fragilis* Prévot, Ann. Inst. Past., *60*, 1938, 290.) From Latin *fragilis*, fragile.

Rods with rounded ends, staining more deeply at the poles, occurring singly and in pairs. Non-motile. Gram-negative.

Gelatin: No liquefaction; small amount of gas.

Agar colonies: Small, gray, irregular.

Broth: Turbid.

Indole not formed.

Hydrogen sulfide not formed.

Litmus milk: No coagulation. Slight amount of gas.

Nitrites not produced from nitrates.

Acid from fructose, maltose, sucrose, galactose, glucose and arabinose. Some strains produce acid from lactose (Weinberg et al., Les Microbes Anaérobies, 1937, 720).

Anaerobic.

Optimum temperature 37°C.

Pathogenicity: Some strains produce subcutaneous abscesses in rabbits, guinea pigs or mice.

Source and habitat: From acute appendicitis, pulmonary gangrene, abscesses of the urinary tract, and septicaemias in man.

2. **Bacteroides serpens** (Veillon and Zuber) Hauduroy et al. (*Bacillus serpens* Veillon and Zuber, Arch. Méd. Exp. et Anat. Path., *10*, 1898, 870; *Bacillus radiiformis* Rist and Guillemot, Arch. Méd. Exp. et Anat. Path., 1904; Hauduroy et al., Dict. d. Bact. Path., 1937, 74; *Zuberella serpens* Prévot, Ann. Inst. Past., *60*, 1938, 293.) From Latin *serpens*, creeping.

Rods: Thick, with rounded ends, occurring singly, in pairs, or in short chains. Motile. Gram-negative.

Gelatin: Slow liquefaction, with gas.

Agar colonies: Punctiform.

Deep agar colonies: Small colonies in 48 hours, ray-like growth later. Gas produced.

Broth: Turbid, then flocculent growth; some gas with foul odor.

Hydrogen sulfide not formed.

Litmus milk: Acidified and coagulated in six days, with no digestion.

Acid from fructose, galactose, maltose and lactose.

Coagulated egg white and serum not liquefied.

Anaerobic.

Optimum temperature 37°C.

Experimental pathogenicity: Some strains produce abscesses in rabbits, guinea pigs and mice.

Source and habitat: Acute appendicitis, mastoiditis, pulmonary gangrene, bile tract of dog, and sea water.

3. **Bacteroides funduliformis** (Hallé) Bergey et al. (*Bacillus funduliformi* Hallé, Inaug. Diss., Paris, 1898; *Bacillus thetoides* Rist, Thèse de Paris, 1898; Bergey et al., Manual, 3rd ed., 1930, 373; *Spherophorus funduliformis* Prévot, Ann. Inst. Past., *60*, 1938, 298.) From Latin *funduliformis*, sausage-shaped.

Rods: 1.5 to 3.0 microns long in pus, often spindle-shaped. Extremely pleomorphic in culture media, showing irregular filamentous and branching forms. Non-motile. Gram-negative.

Gelatin: Not liquefied.

Deep agar colonies: Lenticular, with some gas and foul odor.

Broth: Flocculent growth.

Glucose broth: Rapid growth with gas and foul odor.

Indole not formed; although sometimes found in old cultures.

Hydrogen sulfide is formed in small amounts.

Litmus milk: Acid and coagulation by some strains.

Acid and gas from fructose, glucose and maltose. Some strains ferment mannitol, sucrose and lactose.

Anaerobic.

Optimum temperature 37°C.

Experimental pathogenicity: Some strains are pathogenic for rabbits and guinea pigs but not for white rats and mice.

Source and habitat: Female genitalia, urinary infections, puerperal infections, acute appendicitis, otitis, pulmonary gangrene, liver abscesses, septicaemias and intestinal tract.

4. **Bacteroides siccus** Eggerth and Gagnon. (Eggerth and Gagnon, Jour. Bact., *25*, 1933, 410; *Spherophorus siccus* Prévot, Ann. Inst. Past., *60*, 1938, 299.) From Latin *siccus*, dry.

Short, thick rods: About 1.0 micron long. In glucose broth they are coccoid and often grow in short chains. Non-motile. Gram-negative.

Gelatin: Not liquefied.

Blood agar colonies: Elevated, dry, difficult to emulsify, 1.0 to 1.5 mm in diameter.

Broth: Growth occurs as a powdery sediment with a clear supernatant fluid.

Indole not formed.

Hydrogen sulfide is formed.

Milk: Unchanged.

Nitrites not produced from nitrates.

Acid but no gas from fructose. No acid or gas from glucose, glycerol, mannitol, sorbitol, arabinose, salicin, trehalose, amygdalin, cellobiose, glycogen, rhamnose, xylose or lactose.

Non-pathogenic for white mice and rabbits.

Anaerobic.

Distinctive characters: Gas is formed in small amounts from peptone. Phenol red and brom cresol purple are decolorized in meat infusion broth.

Source: Two strains isolated from human feces.

Habitat: Probably intestinal canal of mammals.

5. **Bacteroides coagulans** Eggerth and Gagnon. (Eggerth and Gagnon, Jour. Bact., *25*, 1933, 409; *Pasteurella coagulans* Prévot, Ann. Inst. Past., *60*, 1938, 292.) From Latin *coagulans*, coagulating.

Rods: 0.5 to 2.0 microns long. Bipolar staining. Non-motile. Gram-negative.

Gelatin: Liquefied in 8 to 12 days.

Blood agar colonies: Soft, transparent, 0.5 mm in diameter.

Broth: Diffuse growth.

Indole is formed.

Hydrogen sulfide is formed.

Milk: Coagulated in 8 days without acid production. The coagulum partly redissolves after 3 to 4 weeks.

Nitrites not produced from nitrates.

Non-pathogenic for white mice and rabbits.

Anaerobic.

Distinctive characters: No acid or gas from carbohydrates. A small amount of gas is formed from peptone. Phenol red and brom cresol purple are decolorized in a meat infusion broth.

Source: One strain isolated from human feces.

Habitat: Probably intestinal canal of mammals.

6. **Bacteroides varius** Eggerth and Gagnon. (Eggerth and Gagnon, Jour. Bact., *25*, 1933, 409; *Spherophorus varius* Prévot, Ann. Inst. Past., *60*, 1938, 299.) From Latin *varius*, diverse.

Rods: 1.0 to 3.0 microns long. Staining uneven. Non-motile. Gram-negative.

Gelatin: Not liquefied in 45 days.

Blood agar colonies: Very flat cones, 2.0 to 3.0 mm in diameter.

Broth: Diffusely clouded.

Indole is formed.

Hydrogen sulfide produced.

Milk: Not acidified or coagulated.

Nitrites not produced from nitrates.

Acid and gas from fructose, galactose, glucose and mannose. No acid or gas from esculin, amygdalin, arabinose, cellobiose, dextrin, glycerol, glycogen, inulin, lactose, maltose, mannitol, melezitose,

raffinose, rhamnose, salicin, sorbitol, starch, sucrose, trehalose or xylose.

Non-pathogenic for white mice and rabbits.

Anaerobic.

Distinctive characters: Gas is formed from peptone. Brom cresol purple and phenol red are decolorized in a meat infusion broth.

Source: Two strains isolated from human feces.

Habitat: Probably intestinal canal of mammals.

7. **Bacteroides inaequalis** Eggerth and Gagnon. (Eggerth and Gagnon, Jour. Bact., *25*, 1933, 407; *Spherophorus inaequalis* Prévot, Ann. Inst. Past., *60*, 1938, 298.) From Latin *inaequalis*, unequal.

Rods: Wide variation in size and form. Marked pleomorphism on blood agar. Non-motile. Gram-negative.

Gelatin: Not liquefied in 45 days.

Blood agar colonies: Pin-point in size.

Broth: Diffusely clouded.

Indole is formed.

Hydrogen sulfide is produced.

Milk: Acidified but not coagulated.

Nitrites not produced from nitrates.

Acid but no gas from esculin, amygdalin, arabinose, fructose, galactose, glucose, lactose, maltose, mannose, raffinose, salicin, sucrose and xylose. No acid or gas from cellobiose, dextrin, glycerol, glycogen, inulin, mannitol, melezitose, rhamnose, sorbitol, starch and trehalose.

Non-pathogenic for white mice and rabbits.

Anaerobic.

Distinctive characters: Forms small amount (5 per cent in Smith tube) of gas from peptone water in the complete absence of carbohydrates. None of this gas is absorbed by alkali. Rapidly decolorizes brom cresol purple and phenol red in meat infusion broth; slowly or not at all in peptone water.

Source: One strain isolated from human feces.

Habitat: Probably intestinal canal of mammals.

8. **Bacteroides insolitus** Eggerth and Gagnon. (Eggerth and Gagnon, Jour. Bact., *25*, 1933, 408; *Ristella insolita* Prévot, Ann. Inst. Past., *60*, 1938, 291.) From Latin *insolitus*, uncommon.

Short thick rods: 1.0 to 2.0 microns long. Often slender, curved, 2.0 to 3.0 microns long. Non-motile. Gram-negative.

Gelatin: Not liquefied in 45 days.

Blood agar colonies: Minute, transparent.

Broth: Heavy, diffuse growth.

Indole is formed.

Hydrogen sulfide is formed.

Milk: Acidified and coagulated in 30 to 35 days.

Nitrites not produced from nitrates.

Acid but no gas from fructose, galactose, glucose, glycerol, lactose, maltose and mannose. No acid or gas from esculin, amygdalin, arabinose, cellobiose, dextrin, glycogen, inulin, mannitol, melezitose, raffinose, rhamnose, salicin, sorbitol, starch, sucrose, trehalose and xylose.

Non-pathogenic for white mice and rabbits.

Anaerobic.

Distinctive characters: Brom cresol purple and phenol red are rapidly decolorized in a meat infusion broth. A small amount of gas is formed from peptone.

Source: One strain isolated from human feces.

Habitat: Probably intestinal canal of mammals.

9. **Bacteroides vescus** Eggerth and Gagnon. (Eggerth and Gagnon, Jour. Bact., *25*, 1933, 406; *Fusiformis vescus* Prévot, Ann. Inst. Past., *60*, 1938, 300.) From Latin *vescus*, small or weak.

Slender, pointed rods: 1.0 to 2.0 microns long, sometimes slightly curved.

Bipolar staining. Non-motile. Gram-negative.

Gelatin: Liquefied in 8 to 25 days.

Blood agar colonies: Very minute and transparent.

Broth: Diffusely clouded.

Indole not formed.

Hydrogen sulfide not produced.

Milk: Neither acidified nor coagulated.

Nitrites not produced from nitrates.

Peptone: No gas.

Acid but no gas from cellobiose (in 30 days), dextrin, glucose, maltose, mannose and rhamnose. No acid or gas from esculin, amygdalin, arabinose, galactose, mannitol, melezitose, raffinose, salicin, sorbitol, starch, sucrose, trehalose, xylose, glycerol, glycogen, inulin, lactose or fructose.

Non-pathogenic for white mice and rabbits.

Anaerobic.

Source: One strain isolated from human feces.

Habitat: Probably intestinal canal of mammals.

10. **Bacteroides exiguus** Eggerth and Gagnon. (Eggerth and Gagnon, Jour. Bact., *25*, 1933, 407; *Ristella exigua* Prévot, Ann. Inst. Past., *60*, 1938, 292.) From Latin *exiguus*, small and narrow.

Very small slender rods: 0.5 to 1.0 micron long, occurring singly and in pairs. Non-motile. Gram-negative.

Gelatin: Liquefied in 16 to 20 days.

Blood agar colonies: These are of two types. One is pin-point in size, the other is large, gray, moist, 1.0 to 1.5 mm in diameter.

Broth: Diffusely clouded.

Indole not formed.

Hydrogen sulfide not formed.

Milk: Acidified and may or may not be coagulated in 35 to 40 days.

Nitrites not produced from nitrates.

Peptone: No gas.

Acid but no gas from fructose, galactose, glucose, lactose, maltose, mannose, sucrose and trehalose. One strain ferments raffinose. No acid or gas from esculin, amygdalin, arabinose, cellobiose, dextrin, glycerol, glycogen, inulin, mannitol, melezitose, rhamnose, salicin, sorbitol, starch or xylose.

Non-pathogenic for white mice and rabbits.

Anaerobic.

Source: Two strains isolated from human feces.

Habitat: Probably intestinal canal of mammals.

11. **Bacteroides uncatus** Eggerth and Gagnon. (Eggerth and Gagnon, Jour. Bact., *25*, 1933, 404; *Ristella uncata* Prévot, Ann. Inst. Past., *60*, 1938, 291.) From Latin *uncatus*, hooked at the tip.

Rods: Extreme variations in size and form. The ordinary length is 5.0 to 8.0 microns. Curved and hooked forms common. Non-motile. Gram-negative.

Gelatin: Liquefied in 16 days.

Blood agar colonies: Very minute and transparent.

Broth: Turbid, growth is slow and light.

Indole not formed.

Hydrogen sulfide not formed.

Milk: Not acidified or coagulated.

Nitrites not produced from nitrates.

Peptone: No gas.

Acid but no gas after 8 to 30 days of incubation from dextrin, fructose, galactose, glucose, lactose, maltose, raffinose, rhamnose, salicin, starch and sucrose. No acid from esculin, amygdalin, arabinose, cellobiose, glycerol, glycogen, inulin, mannitol, mannose, melezitose, sorbitol, trehalose or xylose.

Non-pathogenic for white mice and rabbits.

Anaerobic.

Source: One strain isolated from human feces.

Habitat: Probably intestinal canal of mammals.

12. **Bacteroides vulgatus** Eggerth and Gagnon. (Eggerth and Gagnon, Jour.

Bact., *25*, 1933, 401; *Pasteurella vulgata* Prévot, Ann. Inst. Past., *60*, 1938, 292.) From Latin *vulgatus*, common.

Oval rods: 0.7 to 2.5 microns long, usually occurring singly, sometimes in pairs. One strain formed filaments 10 microns long. Stain solidly, some strains show bipolar staining. Morphology very variable in glucose broth. Non-motile. Gram-negative.

Gelatin: Liquefied in 4 to 20 days by all but one strain.

Blood agar colonies: Soft, translucent, grayish, elevated, 1.5 to 2.0 mm in diameter. Half of the strains are hemolytic.

Broth: Heavy and diffuse growth.

Indole not formed.

Hydrogen sulfide is formed.

Milk: Acidified. Coagulated by some strains in 5 to 25 days.

Nitrites not produced from nitrates.

Acid and a small amount of gas from arabinose, dextrin, fructose, galactose, glucose, glycogen, inulin, lactose, maltose, mannose, raffinose, rhamnose, starch, sucrose and xylose. Seven strains fermented esculin. No acid or gas from amygdalin, cellobiose, glycerol, mannitol, melezitose, salicin, sorbitol, trehalose, dulcitol, erythritol or inositol.

Non-pathogenic for white mice and rabbits.

Anaerobic.

Distinctive characters: Does not form indole; does not produce gas from peptone. This is the commonest species found in the feces of adults. Differs from *Bacteroides incommunis* in that it does not ferment amygdalin and cellobiose, but does ferment glycogen and starch. Liquefies gelatin.

Source: Thirty-eight strains isolated from human feces.

Habitat: Probably intestinal canal of mammals.

13. **Bacteroides incommunis** Eggerth and Gagnon. (Eggerth and Gagnon, Jour. Bact., *25*, 1933, 402; *Ristella incommunis* Prévot, Ann. Inst. Past., *60*, 1938, 291.) From Latin *incommunis*, not common.

Rods: 0.5 to 1.5 by 1.0 to 3.0 microns, occurring singly. Stain solidly. Non-motile. Gram-negative.

Gelatin: Not liquefied.

Blood agar colonies: Elevated, slightly yellowish, 1 mm in diameter. One strain formed soft colonies; the other was stringy when emulsified.

Broth: Growth is diffuse.

Indole not formed.

Hydrogen sulfide is formed.

Milk: Acidified but not coagulated; coagulates promptly on boiling.

Nitrites not produced from nitrates.

Peptone: No gas.

Acid and a small amount of gas from amygdalin, arabinose, cellobiose, dextrin, fructose, galactose, glucose, inulin, lactose, maltose, mannose, raffinose, rhamnose, sucrose and xylose. One strain fermented glycogen and starch. No action on esculin, glycerol, mannitol, melezitose, salicin, sorbitol or trehalose.

Non-pathogenic for white mice and rabbits.

Anaerobic.

Source: Two strains isolated from human feces.

Habitat: Probably intestinal canal of mammals.

14. **Bacteroides distasonis** Eggerth and Gagnon. (Eggerth and Gagnon, Jour. Bact., *25*, 1933, 403; *Ristella distasonis* Prévot, Ann. Inst. Past., *60*, 1938, 291.) Named for Distaso, Roumanian bacteriologist.

Rods: 0.5 to 0.8 by 1.5 to 2.5 microns, occurring singly. Staining solidly and having rounded ends. Some strains show a few bacilli 5.0 to 8.0 microns long. Non-motile. Gram-negative.

Gelatin: Not liquefied by 16 strains. The remaining 4 liquefied gelatin in 35 to 50 days.

Blood agar colonies: Soft, grayish, elevated colonies, 1.0 to 1.5 mm in diameter. Two strains markedly hemolytic.

Broth: Growth is diffuse.

Indole not formed.

Hydrogen sulfide is produced.

Milk: Acidified. All but 4 strains coagulate milk.

Nitrites not produced from nitrates.

Peptone: No gas.

Acid but no gas from amygdalin, cellobiose, dextrin, fructose, galactose, glucose, inulin, lactose, maltose, mannose, melezitose, raffinose, rhamnose, salicin, sucrose, trehalose and xylose. Fifteen strains ferment esculin. Fifteen strains slowly ferment starch. No acid or gas from arabinose, glycogen, glycerol, mannitol or sorbitol.

Non-pathogenic for white mice and rabbits.

Anaerobic.

Distinctive characters: Usually fails to liquefy gelatin. Fails to ferment arabinose.

Source: Twenty strains isolated from human feces.

Habitat: Probably intestinal canal of mammals.

15. **Bacteroides tumidus** Eggerth and Gagnon. (Eggerth and Gagnon, Jour. Bact., *25*, 1933, 405; *Ristella tumida* Prévot, Ann. Inst. Past., *60*, 1938, 292.) From Latin *tumidus*, swollen.

Small, thick oval rods: 1.0 to 1.5 microns long and occurring singly. The staining is solid. On glucose broth many swollen forms with irregular staining from 1.0 to 4.0 by 1.5 to 10 microns. The bodies of these swollen forms are usually very pale, with only the ends staining. Non-motile. Gram-negative.

Gelatin: Liquefied in 12 to 20 days.

Blood agar colonies: Soft, grayish, elevated colonies, 1 mm in diameter.

Broth: Heavy, diffuse growth.

Indole not formed.

Hydrogen sulfide is produced.

Milk: Acidified but not coagulated.

Nitrites not produced from nitrates.

Peptone: No gas.

Acid but no gas from dextrin, fructose, galactose, glucose, glycogen, inulin, lactose, maltose, mannose, raffinose, sorbitol, starch and sucrose. No acid or gas from esculin, amygdalin, arabinose, cellobiose, glycerol, mannitol, melezitose, rhamnose, salicin, trehalose or xylose.

Non-pathogenic for white mice and rabbits.

Anaerobic.

Source: Four strains isolated from human feces.

Habitat: Probably intestinal canal of mammals.

16. **Bacteroides convexus** Eggerth and Gagnon. (Eggerth and Gagnon, Jour. Bact., *25*, 1933, 406; *Pasteurella convexa* Prévot, Ann. Inst. Past., *60*, 1938, 292.) From Latin *convexus*, convex.

Thick, oval rods: 0.8 to 1.5 microns long, occurring singly or in pairs. In glucose broth, the rods are usually 2.0 to 3.0 microns long. Non-motile. Gram-negative.

Gelatin: Liquefied in 20 to 30 days.

Blood agar colonies: Elevated, grayish, somewhat opaque colonies, 1.0 to 1.5 mm in diameter.

Broth: Heavy diffuse growth.

Indole not formed.

Hydrogen sulfide is produced.

Milk: Acidified and coagulated in 4 days.

Nitrites not produced from nitrates.

Peptone: No gas.

Acid and a small amount of gas from esculin, amygdalin, cellobiose, dextrin, fructose, galactose, glucose, glycogen, inulin, lactose, maltose, mannose, raffinose, starch, sucrose and xylose. No acid or gas from arabinose, glycerol, mannitol, melezitose, rhamnose, salicin, sorbitol or trehalose.

Non-pathogenic for white mice and rabbits.

Anaerobic.

Source: Five strains isolated from human feces.

Habitat: Probably intestinal canal of mammals.

17. **Bacteroides ovatus** Eggerth and Gagnon. (Eggerth and Gagnon, Jour. Bact., *25*, 1933, 405; *Pasteurella ovata* Prévot, Ann. Inst. Past., *60*, 1938, 292.) From Latin *ovatus*, egg-shaped.

Small oval rods: 0.5 to 1.0 by 1.0 to 2.0 microns, occurring singly. Stains solidly. Non-motile. Gram-negative.

Gelatin: Liquefied in 4 days.

Blood agar colonies: Soft, grayish, elevated colonies, 1.0 to 1.5 mm in diameter.

Broth: Diffuse, heavy growth.

Indole is formed.

Hydrogen sulfide is produced.

Milk: Acidified and coagulated in 4 days.

Nitrites not produced from nitrates.

Peptone: No gas.

Acid and a small amount of gas from esculin, amygdalin, cellobiose, dextrin, fructose, galactose, glucose, glycogen, inulin, lactose, maltose, mannose, raffinose, rhamnose, starch, sucrose and xylose. No acid or gas from arabinose, glycerol, mannitol, melezitose, salicin, sorbitol or trehalose.

Non-pathogenic for white mice and rabbits.

Anaerobic.

Source: One strain isolated from human feces.

Habitat: Probably intestinal canal of mammals.

18. **Bacteroides uniformis** Eggerth and Gagnon. (Eggerth and Gagnon, Jour. Bact., *25*, 1933, 400; *Ristella uniformis* Prévot, Ann. Inst. Past., *60*, 1938, 291.) From Latin *uniformis*, of a single form.

Small rods: 0.8 to 1.5 microns long, occurring singly, with rounded ends. Stain heavier at poles and around periphery. Non-motile. Gram-negative.

Gelatin: Liquefied by two strains in 15 to 40 days. Six strains did not liquefy.

Blood agar colonies: Transparent, soft, elevated, 0.5 to 0.75 mm in diameter.

Broth: Diffuse growth.

Indole formed.

Hydrogen sulfide produced slowly or not at all.

Milk: Acidified and coagulated in 8 to 12 days.

Nitrites not produced from nitrates.

Peptone: No gas.

Acid but no gas from esculin, amygdalin, arabinose, cellobiose, dextrin, fructose, galactose, glucose, glycogen, inulin, lactose, maltose, mannose, melezitose, raffinose, salicin, starch, sucrose, trehalose and xylose. No acid or gas from glycerol, mannitol, rhamnose, sorbitol, dulcitol, erythritol or inositol.

Non-pathogenic for white mice and rabbits.

Anaerobic.

Distinctive characters: Forms indole. Resembles *Bacteroides vulgatus*.

Source: Eight strains isolated from human feces.

Habitat: Probably intestinal canal of mammals.

19. **Bacteroides thetaiotaomicron** (Distaso) Castellani and Chalmers. (*Bacillus thetaiotaomicron* Distaso, Cent. f. Bakt., I Abt., Orig., *62*, 1912, 444; Castellani and Chalmers, Man. Trop. Med., 3rd ed., 1919, 960; *Spherocillus thetaiotaomicron* Prévot, Ann. Inst. Past., *60*, 1938, 300.) The combination theta, iota and omicron is used because the pleomorphic rods have the shape of these Greek letters.

Description taken from Distaso (*loc. cit.*). More complete description will be found in Eggerth and Gagnon (Jour. Bact., *25*, 1933, 399).

Short, plump to oval rods. Stain solidly or only at poles. Sometimes with bar causing organism to resemble Greek letter theta. Motile (Distaso). Non-motile (Eggerth and Gagnon). Gram-negative.

Gelatin: No liquefaction.

Glucose agar colonies: Large, transparent, entire. Sometimes form gas bubbles.

Broth: Turbid.

Egg albumen broth: Albumen not attacked.

Indole is formed.

Hydrogen sulfide produced (Eggerth and Gagnon).

Litmus milk: Acid, coagulated. Curd shrinks with expulsion of turbid whey.

Nitrates not recorded (Distaso). Nitrites not produced from nitrates (Eggerth and Gagnon).

Peptone: No gas (Eggerth and Gagnon).

Acid and gas from esculin, amygdalin, arabinose, fructose, inulin, lactose, cellobiose, dextrin, galactose, glucose, glycogen, maltose, mannose, melezitose, raffinose, rhamnose, salicin, starch, sucrose, trehalose and xylose. Four strains fail to produce gas from any sugar. No acid or gas from glycerol, mannitol or sorbitol (Eggerth and Gagnon).

Anaerobic.

Distinctive characters: Resembles *Bacteroides variabilis* but is not capsulated, does not liquefy gelatin, usually forms gas from sugars, and ferments melezitose and trehalose. Differs from *Bacteroides uniformis* in morphology, forming gas from sugars and in fermenting rhamnose (Eggerth and Gagnon).

Source: Isolated frequently from human feces.

Habitat: Intestinal canal of mammals (common).

20. **Bacteroides variabilis** (Distaso) Castellani and Chalmers. (*Bacillus variabilis* Distaso, Cent. f. Bakt., I Abt., Orig., *62*, 1912, 441; Castellani and Chalmers, Man. Trop. Med., 3rd ed., 1919, 960; *Capsularis variabilis* Prévot, Ann. Inst. Past., *60*, 1938, 293.) From Latin *variabilis*, variable.

Short rods, with rounded ends, occurring singly. Some long flexuous rods. Capsulated. Non-motile. Gram-negative.

Gelatin: No growth on plain gelatin (Distaso); liquefaction (Eggerth and Gagnon, Jour. Bact., *25*, 1933, 400).

Blood agar colonies: Smooth, glistening, elevated and very mucoid, about 1.0 mm in diameter.

Broth: Diffuse growth.

Indole is formed.

Hydrogen sulfide is formed.

Litmus milk: Unchanged (Distaso); acidified and some strains coagulating in 25 to 35 days (Eggerth and Gagnon).

Nitrites not produced from nitrates (Eggerth and Gagnon).

Peptone: No gas.

Acid and gas from glucose, lactose and sucrose (Distaso). Acid and no gas from esculin, amygdalin, arabinose, cellobiose, dextrin, fructose, galactose, glycogen, inulin, lactose, glucose, maltose, mannose, raffinose, rhamnose, salacin, starch, sucrose and xylose. No acid or gas from glycerol, mannitol, melezitose, sorbitol or trehalose (Eggerth and Gagnon).

Non-pathogenic for white mice and rabbits.

Anaerobic.

Optimum temperature 37°C.

Distinctive characters: Capsulated.

Source: Isolated from human feces by Distaso, and by Eggerth and Gagnon (8 strains).

Habitat: Probably intestinal canal of mammals.

21. **Bacteroides gulosus** Eggerth and Gagnon. (Eggerth and Gagnon, Jour. Bact., *25*, 1933, 398; *Spherophorus gulosus* Prévot, Ann. Inst. Past., *60*, 1938, 298.) From Latin *gulosus*, gluttonous.

Small oval rods: 0.8 to 1.0 by 1.0 to 2.0 microns, staining deeper around periphery. Non-motile. Gram-negative.

Gelatin: Liquefied in 2 to 3 weeks.

Blood agar colonies: Soft, gray, entire, elevated, 2 mm in diameter.

Broth: Heavy and diffuse growth.

Indole formed.

Hydrogen sulfide is formed.

Milk: Acidified and coagulated in 4 to 20 days.

Nitrites not produced from nitrates.

Acid and a very small amount of gas from esculin, amygdalin, arabinose, cellobiose, dextrin, fructose, galactose, glycogen, inulin, lactose, glucose, maltose, mannitol, mannose, melezitose, raffinose, rhamnose, salicin, sorbitol, starch, sucrose, trehalose and xylose. Sorbitol and mannitol require 2 to 3 weeks for fermentation. Neither acid nor gas from glycerol, dulcitol, erythritol or inositol.

Peptone: No gas.

Non-pathogenic for white mice and rabbits.

Anaerobic.

Source: Seven strains isolated from human feces.

Habitat: Probably intestinal canal of mammals.

22. **Bacteroides melaninogenicus** (Oliver and Wherry) Roy and Kelly. (*Bacterium melaninogenicum* Oliver and Wherry, Jour. Inf. Dis., *28*, 1921, 341; *Hemophilus melaninogenicus* Bergey et al., Manual, 3rd ed., 1930, 314; *Ristella melaninogenica* Prévot, Ann. Inst. Past., *60*, 1939, 290; Roy and Kelly, in Manual, 5th ed., 1939, 569.) From Greek, black-producing.

Description taken from Oliver and Wherry (*loc. cit.*) and Burdon (Jour. Inf. Dis., *42*, 1928, 161).

Rods: 0.8 by 1.0 to 3.0 microns. Non-motile. Gram-negative.

Serum gelatin stab: Dense flocculent growth at 37°C. No liquefaction.

Blood agar slant: Confluent, black, dry layer. The blood is disintegrated in one to two weeks forming melanin. The medium becomes colorless.

Sodium phosphate broth: Turbid.

Litmus milk: Slow acidification but no coagulation.

Blood serum slant: Fairly luxuriant, white, moist layer.

Acid from fructose, glucose, lactose, maltose, sucrose and mannitol. No acid from galactose.

Non-pathogenic for rabbits, guinea pigs and white mice (Burdon). Anaerobic.

Optimum temperature 37°C.

Distinctive characters: Growth very poor unless fresh body fluids are added to the medium. Grows more readily in mixed culture. When grown on a medium containing haemoglobin, a black pigment is produced (melanin).

Source: Oral cavity, external genitalia, infected surgical wound, urine and feces (Oliver and Wherry).

Habitat: Inhabits healthy mucous membranes of mammals, but may take a part in various pathological processes (Burdon).

23. **Bacteroides caviae** (Vinzent) Hauduroy et al. (*Streptobacillus caviae* Vinzent, Ann. Inst. Past., *42*, 1928, 533; Hauduroy et al., Dict. d. Bact. Path., 1937, 53; *Spherophorus caviae* Prévot, Ann. Inst. Past., *60*, 1938, 299.) From *Cavia*, a genus of rodents.

Rods: Small, sometimes curved. Usually 0.3 to 0.5 by 1.0 to 1.5 microns. Occurring singly and in chains. Pleomorphic in old cultures with long filamentous forms. Non-motile. Gram-negative.

Serum gelatin: No liquefaction.

Serum agar: Surface colonies, small, translucent, slightly raised, adherent to medium in 48 hours. Deep colonies, lenticular, 2 mm in size in 48 hours. Colonies difficult to break up. No gas.

Serum broth: Supernatant fluid clear, with small, stellate colonies, which tend to adhere to walls of the tube. No gas.

Indole not formed in serum peptone water.

Hydrogen sulfide not formed.

Milk: Unchanged.

Coagulated egg white and serum not liquefied.

No acid or gas from carbohydrates.

Pathogenic for guinea pigs, rabbits and mice.

Anaerobic.

Optimum temperature 37°C.

Distinctive characters: No growth unless serum is added to the medium.

Source: From epidemic benign cervical adenitis of guinea pigs.

Habitat: Infected guinea pigs so far as known.

Appendix I: Additional species which may belong here.

Bacteroides laevis (Distaso) Bergey et al. (*Bacillus laevis* Distaso, Cent. f. Bakt., I Abt., Orig., *62*, 1912, 444; Bergey et al., Manual, 1st ed., 1923, 259; not *Bacillus laevis* Frankland and Frankland, Phil. Trans. Roy. Soc. London, *178*, B, 1887, 278.) From feces.

Bacteroides liquefaciens (Distaso) Bergey et al. (*Coccobacillus liquefaciens* Distaso, Cent. f. Bakt., I Abt., Orig., *59*, 1911, 102; Bergey et al., Manual, 1st ed., 1923, 262.) From feces.

Bacteroides rigidus (Distaso) Bergey et al. (*Bacillus rigidus* Distaso, Cent. f. Bakt., I Abt., Orig., *59*, 1911, 103; Bergey et al., Manual, 1st ed., 1923, 263.)

Appendix II*: Prévot (Ann. Inst. Past., *60*, 1938, 285 and Man. de Class. et de Déterm. des Bact. Anaérobies, 1940, 38) has arranged some of the anaerobic, non-spore-forming, Gram-negative, largely parasitic rods in two families, *Ristellaceae* and *Spherophoraceae*, as follows:

Family Ristellaceae Prévot.

(Ann. Inst. Past., *60*, 1938, 288.)

Genus I. Ristella *Prévot.*

(*Loc. cit.*, 289.)

Straight or slightly bent, non-motile rods. Not capsulated. Gram-negative. Anaerobic.

1. *Ristella fragilis.* See *Bacteroides fragilis.*

2. *Ristella melaninogenica.* See *Bacteroides melaninogenicus.*

3. *Ristella haloseptica* (Wyss) Prévot. (*Bacterium halosepticum* Wyss, Mitt. Grenz. Med. u. Chir., *13*, 1904, 199; Prévot, *loc. cit.*, 291.) From a fatal case of osteomyelitis in man. For a description of this species, see Manual, 5th ed., 1939, 570.

4. *Ristella putredinis* (Weinberg et al.) Prévot. (Bacillus A, Heyde, Beitr. z. klin. Chirurg., *76*, 1911, 1; *Bacillus putredinis* Weinberg et al., Les Microbes Anaérobies, 1937, 755; Prévot, *loc. cit.*, 291.) Fifteen strains isolated from acute appendicitis. For a description of this species, see Manual, 5th ed., 1939, 571.

5. *Ristella terebrans* (Brocard and Pham) Prévot. (*Bacillus terebrans* Brocard and Pham, Compt. rend. Soc. Biol., Paris, *117*, 1934, 997; Prévot, *loc. cit.*, 291.) Two strains isolated from cases of gangrenous erysipelas, associated with a streptococcus. For a description of this species, see Manual, 5th ed., 1939, 571.

6. *Ristella furcosa* (Veillon and Zuber) Prévot. (*Bacillus furcosus* Veillon and Zuber, Arch. Méd. Exp. et Anat. Path., *10*, 1898; *Fusiformis furcosus* Topley and Wilson, Princip. Bact. and Immun., 1st ed., *1*, 1931, 302; *Bacteroides furcosus* Hauduroy et al., Dict. d. Bact. Path., 1937, 61; Prévot, *loc. cit.*, 291.) From cases of appendicitis and from lung abscesses. For a description of this species, see Manual, 5th ed., 1939, 572.

7. *Ristella putida* (Weinberg et al.) Prévot. (*Bacillus gracilis putidus* Tissier and Martelly, Ann. Inst. Past., *16*, 1902, 865; *Bacillus putidus* Weinberg et al., Les Microbes Anaérobies, 1937, 790; not *Bacillus putidus* Kern, Arb. bakt. Inst. Karlsruhe, *1*, Heft 4, 1896,

* Rearranged by Mrs. Eleanore Heist Clise, New York State Experiment Station, Geneva, New York, December, 1945.

400; Prévot, *loc. cit.*, 291.) From putrefying meat. For a description of this species, see Manual, 5th ed., 1939, 573.

8. *Ristella clostridiiformis* (Ankersmit) Prévot. (*Bacterium clostridiiformis* Ankersmit, Cent. f. Bakt., I Abt., Orig., *40*, 1906, 115; Prévot, *loc. cit.*, 291.) From the normal intestines of cattle. For a description of this species, see Manual, 5th ed., 1939, 574.

9. *Ristella perfoetens* (Weinberg et al.) Prévot. (*Coccobacillus anaerobius perfoetens* Tissier, Thèse Méd., Paris, 1900; *Bacterium perfoetens* Weinberg et al., Les Microbes Anaérobies, 1937, 790; *Bacteroides perfoetens* Hauduroy et al., Dict. d. Bact. Path., 1937, 67; Prévot, *loc. cit.*, 291.) From the intestines of infants with diarrhoea. For a description of this species, see Manual, 5th ed., 1939, 575.

10. *Ristella thermophila β* (Weinberg et al.) Prévot. (Thermo β, Veillon, Ann. Inst. Past., *36*, 1922, 430; *Bacillus thermophilus β* Weinberg et al., Les Microbes Anaérobies, 1937, 800; Prévot, *loc. cit.*, 291.) From manure. Non-pathogenic.

11. *Ristella thermophila γ* (Weinberg et al.) Prévot. (Thermo γ, Veillon, Ann. Inst. Past., *36*, 1922, 432; *Bacillus thermophilus γ* Weinberg et al., Les Microbes Anaérobies, 1937, 800; Prévot, *loc. cit.*, 291.) From manure. For a description of this species, see Manual, 5th ed., 1939, 575.

12. *Ristella incommunis*. See *Bacteroides incommunis*.

13. *Ristella insolita*. See *Bacteroides insolitus*.

14. *Ristella halosmophila* (Baumgartner) Prévot. (*Bacteroides halosmophilus* Baumgartner, Food Research, *2*, 1937, 321; Prévot, Man. de Class. et de Déterm. des Bact. Anaérobies, 1940, 47.) From salted Mediterranean anchovies. Frequently found in the fish muscle and in the solar salt (the probable infecting agent) in which the fish is packed. For a description of this species, see Manual, 5th ed., 1939, 584.

15. *Ristella naviformis* (Jungano) Prévot. (*Bacillus naviformis* Jungano, Compt. rend. Soc. Biol., Paris, *66*, 1909, 122; Prévot, Ann. Inst. Past., *60*, 1938, 291.) From the large intestine of the rat. For a description of this species, see Manual, 5th ed., 1939, 573.

16. *Ristella lichenis-plani* Prévot. (Bacillus of lichen planus, Jacob and Helmbold, Arch. Derm. Syph., *3*, 1933, 28; Prévot, *loc. cit.*, 291.) From the lesions of an inflammatory skin disease, lichen planus.

17. *Ristella destillationis* (Weinberg et al.) Prévot. (Bacterium, Tunnicliff, Jour. Inf. Dis., *13*, 1913, 283; *Bacterium destillationis* Weinberg et al., Les Microbes Anaérobies, 1937, 762; Prévot, *loc. cit.*, 291.) From a case of chronic bronchitis.

18. *Ristella uniformis*. See *Bacteroides uniformis*.

19. *Ristella distasonis*. See *Bacteroides distasonis*.

20. *Ristella uncata*. See *Bacteroides uncatus*.

21. *Ristella tumida*. See *Bacteroides tumidus*.

22. *Ristella exigua*. See *Bacteroides exiguus*.

23. *Ristella trichoides* (Potez and Compagnon) Prévot. (*Bacillus trichoides* Potez and Compagnon, Compt. rend. Soc. Biol., Paris, *87*, 1922, 339; *Bac-*

teroides trichoides Hauduroy et al., Dict. d. Bact. Path., 1937, 78; Prévot, *loc. cit.*, 292.) From a case of choleocystitis. For a description of this species, see Manual, 5th ed., 1939, 572.

24. *Ristella glutinosa* (Guillemot and Hallé) Prévot. (*Bacillus glutinosus* Guillemot and Hallé, Arch. Méd. Exp. et Anat. Path., *16*, 1904, 599; *Bacteroides glutinosus* Hauduroy et al., Dict. d. Bact. Path., 1937, 61; Prévot, *loc. cit.*, 292.) From purulent pleurisies.

25. *Ristella capillosa* (Tissier) Prévot. (*Bacillus capillosus* Tissier, Ann. Inst. Past., *22*, 1908, 189; Prévot, *loc. cit.*, 292.) From the intestines of infants. For a description of this species, see Manual, 5th ed., 1939, 573.

26. *Ristella cylindroides* (Rocchi) Prévot. (*Bacterium cylindroides* Rocchi, Lo stato actuale delle nostre cognizioni sui germi anaerobi Gamberine e Parmezziani, Bologna, 1908; Prévot, *loc. cit.*, 292.) From the human intestine. For a description of this species, see Manual, 5th ed., 1939, 574.

Genus II. Pasteurella *Trevisan.*

Four species. *See Bacteroides vulgatus*, *Bacteroides ovatus*, *Bacteroides convexus*, and *Bacteroides coagulans*.

Genus III. Dialister *Bergey et al.*

Two species. See *Dialister*.

Genus IV. Capsularis *Prévot.*

(*Loc. cit.*, 290.)

Characters as for the genus *Ristella*, but capsulated.

1. *Capsularis zoogleiformans* (Weinberg et al.) Prévot. (*Bacillus mucosus anaerobius* Prausnitz, Cent. f. Bakt., I Abt., Orig., *89*, 1922, 126; *Bacterium zoogleiformans* Weinberg et al., Les Microbes Anaérobies, 1937, 725; *Bacteroides praussnitzii* Hauduroy et al., Dict. d. Bact. Path., 1937, 68; Prévot, *loc. cit.*, 293.) From a purulent empyema in man. For a description of this species, see Manual, 5th ed., 1939, 576.

2. *Capsularis mucosus* (Weinberg et al.) Prévot. (*Coccobacterium mucosum anaerobicum* Klinger, Cent. f. Bakt., I Abt., Orig., *62*, 1912, 186; *Bacterium mucosum* Weinberg et al., Les Microbes Anaérobies, 1937, 727; *Bacteroides viscosus* Hauduroy et al., Dict. d. Bact. Path., 1937, 81; Prévot, *loc. cit.*, 293.) From a brain abscess following bronchiectasis in man. For a description of this species, see Manual, 5th ed., 1939, 575.

3. *Capsularis variabilis*. See *Bacteroides variabilis*.

Genus V. Zuberella *Prevot.*

(*Loc. cit.*, 290.)

Characters as for the genus *Ristella*, but motile with peritrichous flagella.

1. *Zuberella serpens*. See *Bacteroides serpens*.

2. *Zuberella praeacuta* (Tissier) Prévot. (*Coccobacillus praeacutus* Tissier, Ann. Inst. Past., *22*, 1908, 189; Prévot, *loc. cit.*, 293.) From the intestines of infants. For a description of this species, see Manual, 5th ed., 1939, 577.

3. *Zuberella clostridiiformis mobilis* Prévot. (*Bacterium clostridiiformis* Choukévitch, Ann. Inst. Past., *25*, 1911, 345; Prévot, *loc. cit.*, 293.) From the intestines of a horse. Choukévitch considered his organism the same as Ankersmit's *Bacterium clostridiiformis*, although the former was motile.

4. *Zuberella aquatilis* Prévot. (Spray and Laux, Amer. Water Works Assoc.

22, 1930, 235; Prévot, *loc. cit.*, 293.) From river water. For a description of this organism, see Manual, 5th ed., 1939, 577.

5. *Zuberella variegata* (Distaso) Prévot. (*Bacillus variegatus* Distaso, Cent. f. Bakt., I Abt., Orig., *62*, 1912, 445; *Bacteroides variegatus* Castellani and Chalmers, Man. Trop. Med., 3rd ed., 1919, 960; Prévot, *loc. cit.*, 293.) From the intestines. For a description of this species, see Manual, 5th ed., 1939, 578.

6. *Zuberella rhinitis* (Tunnicliff) Prévot. (*Bacillus rhinitis* Tunnicliff, Jour. Inf. Dis., *16*, 1915, 493; Prévot, *loc. cit.*, 293.) Thirty-two strains isolated from the nasopharynx in human beings suffering from pharyngitis, tonsilitis, bronchitis and rhinitis, as well as from the nasal mucosa of normal human beings, rabbits, guinea pigs and dogs. For a description of this species, see Manual, 5th ed., 1939, 576.

Family Spherophoraceae Prévot.

(*Loc. cit.*, 289.)

Genus I. Spherophorus *Prévot.*

(*Loc. cit.*, 297.)

Very pleomorphic rods. Metachromatic granules common in elongated forms. Non-motile. Non-spore-forming. Gram-negative.

1. *Spherophorus necrophorus* (Flügge) Prévot. (Bacillus der Kälberdiphtherie, Loeffler, Mitteil. kaiserl. Gesundheitsamte, *2*, 1884, 493; *Bacillus diphtheriae vitulorum* Flügge, Die Mikroorganismen, 2 Aufl., 1886, 265; *Bacillus necrophorus* Flügge, *ibid.*, 273; *Bacillus diphtheriae-vitulorum* Trevisan, I generi e le specie delle Batteriacee, 1889, 13; *Bacillus filiformis* Shütz; not *Bacillus filiformis* Tils, Ztschr. f. Hyg., *9*, 1890, 294; not *Bacillus filiformis* Migula, Syst. d. Bakt., *2*, 1900, 587; Nekrosebacillen, Bang, Maanedskrift f. Dyrleager, *2*, 1890, 235; *Streptothrix cuniculi* Schmorl, Deut. Ztschr. f. Tiermed., *17*, 1891, 376; *Actinomyces cuniculi* Gasperini, Mittheil. 11 Internat. Med. Congr. Rome, see Cent. f. Bakt., *15*, 1894, 684; not *Actinomyces cuniculi* Erikson, Med. Res. Council Spec. Rept. Ser. 203, 1935, 32; *Oospora diphtheriae vitulorum* Lehmann and Neumann, Bakt. Diag., 1 Aufl., *2*, 1896, 393; *Actinomyces necrophorus* Lehmann and Neumann, Bakt. Diag., 2 Aufl., *2*, 1899, 434; *Streptothrix necrophora* Kitt, Bakterienkunde, 1899; *Corynebacterium necrophorum* Lehmann and Neumann, Bakt. Diag., 4 Aufl., *2*, 1907, 531; *Bacillus necroseos* Salomonsen, quoted from Lehmann and Neumann, *ibid.*, 532; *Cladothrix cuniculi* Macé, Traité de Bact., 6th ed., *2*, 1913, 753; *Bacterium necrophorum* Lehmann and Neumann, Bakt. Diag., 7 Aufl., *2*, 1927, 504; *Fusiformis necrophorus* Topley and Wilson, Princip. Bact. and Immun., 1st ed., *1*, 1931, 299; Prévot, Ann. Inst. Past., *60*, 1938, 298.) Because of the importance of this organism, a description is included here:

Rods: 0.5 to 1.5 microns wide, forming long filaments, up to 80 to 100 microns long. Some authors report branching, others deny this. Short forms are reported by Schmorl to be motile. Gram-negative.

Gelatin stab: No liquefaction.

Agar colonies: Small, dirty-white, circular, opaque, with yellowish center under low power lens. Margin floccose.

Agar stab: Yellowish colonies along needle track. Gas bubbles produced.

Coagulated blood serum: Small, whitish colonies, becoming opaque, fimbriate.

Broth: Turbid, with gas. Cheese-like odor.

Indole is formed.

Litmus milk: Cheese-like odor. Acidified and generally coagulated.

Nitrites not produced from nitrates.

Anaerobic.

Optimum temperature 37°C.

Produces a soluble exotoxin.

Source and habitat: Causes diphtheria in cattle with multiple sclerotic abscesses; gangrenous dermatitis in horses and mules; multiple necrotic foci in liver of cattle and hogs. One case of human infection reported. Transmissible to mice and rabbits.

2. *Spherophorus funduliformis*. See *Bacteroides funduliformis*.

3. *Spherophorus necrogenes* (Weinberg et al.) Prévot. (Bacillus, Kawamura, Jour. Jap. Soc. Vet. Sci., *5*, 1926, 22; *Bacillus necrogenes* Weinberg et al., Les Microbes Anaérobies, 1937, 381; Prévot, *loc. cit.*, 298.) From epidemic abscesses in hens.

4. *Spherophorus necroticus* (Nativelle) Prévot. (*Bacillus necroticus* Nativelle, 1936, see Weinberg et al., Les Microbes Anaérobies, 1937, 693; Prévot, *loc. cit.*, 298.) From a case of gangrenous appendicitis. For a description of this species, see Manual, 5th ed., 1939, 580.

5. *Spherophorus peritonitis* Prévot. (Bacillus, Ghon and Sachs, Cent. f. Bakt., I Abt., Orig., *38*, 1905, 1 and 131; Prévot, *loc. cit.*, 298.) From peritoneal exudate.

6. *Spherophorus gulosus*. See *Bacteroides gulosus*.

7. *Spherophorus inaequalis*. See *Bacteroides inaequalis*.

8. *Spherophorus varius*. See *Bacteroides varius*.

9. *Spherophorus siccus*. See *Bacteroides siccus*.

10. *Spherophorus mortiferus* (Harris) Prévot. (*Bacillus mortiferus* Harris, Jour. Exp. Med., *6*, 1901, 519; Prévot, *loc. cit.*, 299.) From a liver abscess in man. For a description of this species, see Manual, 5th ed., 1939, 581.

11. *Spherophorus freundi* (Hauduroy et al.) Prévot. (Freund, Cent. f. Bakt., I Abt., Orig., *88*, 1922, 9; Bacterium of Freund, Weinberg et al., Les Microbes Anaérobies, 1937, 706; *Bacteroides freundii* Hauduroy et al., Dict. d. Bact. Path., 1937, 57; Prévot, *loc. cit.*, 299.) From a purulent meningitis following otitis in man. For a description of this species, see Manual, 5th ed., 1939, 581.

12. *Spherophorus pyogenes* (Hauduroy et al.) Prévot. (Buday, Cent. f. Bakt., I Abt., Orig., *77*, 1916, 453; *Bacillus pyogenes anaerobius* Bela-Johan, Cent. f. Bakt., I Abt., Orig., *87*, 1922, 290; *Bacteroides pyogenes* Hauduroy et al., Dict. d. Bact. Path., 1937, 69; Prévot, *loc. cit.*, 299.) From abscesses of the liver and lungs following septic war wounds. Also from the blood stream following tonsillectomies. For a description of this species, see Manual, 5th ed., 1939, 582.

13. *Spherophorus gonidiaformans* (Tunnicliff and Jackson) Prévot. (*Bacillus gonidiaformans* Tunnicliff and Jackson, Jour. Inf. Dis., *36*, 1925, 430; *Actinomyces gonadiformis* (sic) Bergey et al., Manual, 3rd ed., 1930, 469; *Bacteroides gonidiaformans* Hauduroy et al., Dict. d. Bact. Path., 1937, 62; Prévot, *loc. cit.*, 299.) From a tonsil. For a description of this species, see Manual, 5th ed., 1939, 582.

14. *Spherophorus floccosus* (Weinberg et al.) Prévot. (*Streptobacillus pyogenes floccosus* Couromont and Cade, Arch. Med. Exp., *12*, 1900, 393; *Bacillus floccosus* Weinberg et al., Les Microbes Anaérobies, 1937, 698; not *Bacillus floccosus* Kern, Arb. bakt. Inst. Karlsruhe, *1*, Heft 4, 1896, 424; *Bacteroides floccosus* Hauduroy et al., Dict. d. Bact.

Path., 1937, 55; Prévot, *loc. cit.*, 299.) From blood in pyemia of man. For a description of this species, see Manual, 5th ed., 1939, 580.

15. *Spherophorus influenzaeformis* (Russ) Prévot. (*Bacillus influenzaeformis* Russ, Cent. f. Bakt., I Abt., Orig., *39*, 1905, 357; *Bacteroides russii* Hauduroy et al., Dict. d. Bact. Path., 1937, 73; Prévot, *loc. cit.*, 299.) One strain isolated from a perianal abscess and two strains from purulent meningitis in man. For a description of this species, see Manual, 5th ed., 1939, 583.

16. *Spherophorus caviae*. See *Bacteroides caviae*.

Genus II. **Spherocillus** *Prévot.*

(*Loc. cit.*, 297.)

Characters as for the genus *Spherophorus*, but motile with peritrichous flagella.

1. *Spherocillus bullosus* (Distaso) Prévot. (*Bacillus bullosus* Distaso, Cent. f. Bakt., I Abt., Orig., *62*, 1912, 443; *Bacteroides bullosus* Castellani and Chalmers, Man. Trop. Med., 3rd ed., 1919, 960; Prévot, *loc. cit.*, 300.) From the intestinal canal. For a description of this species, see Manual, 5th ed., 1939, 583.

2. *Spherocillus thetaiotaomicron*. See *Bacteroides thetaiotaomicron*.

3. *Spherocillus wirthi* Prévot. (Bacillus, Wirth, Cent. f. Bakt., I Abt., Orig., *105*, 1928, 201; Prévot, *loc. cit.*, 300.) From a case of acute otitis.

Appendix III: The following additional species have been found in the literature.

Actinomyces pseudonecrophorus Harris and Brown. (Bull. Johns Hopkins Hosp., *40*, 1927, 203.) From the uterus in cases of puerperal infection. Probably should be classified near *Spherophorus necrophorus*. For a description of this species, see Manual, 5th ed., 1939, 579.

Bacillus anaerobius gracilis Lewkowicz. (Arch. Méd. Exp., *13*, 1901, 633.) From the mouths of infants.

Bacillus angulosus Garnier and Simon. (Presse Méd., 1909, 473.) From the blood of an infant with typhoid fever.

Bacillus annuliformans Massini. (Ztschr. f. gesam. Exp. Med., 1913, 81.) From a tuberculous cavity of man. Pathogenic.

Bacillus circularis major Heurlin. (Bakt. Unters. d. Keimgehaltes im Genitalkanale d. fiebernden Wöchnerinnen. Helsingfors, 1910, 168.) From the genital canal. Anaerobic. Gram-negative.

Bacillus limitans Heurlin. (*Ibid.*, 165.) From the genital canal. Anaerobic. Gram-negative.

Bacillus nebulosus Hallé. (Hallé, Thèse de Paris, 1898; not *Bacillus nebulosus* Vincent, Ann. Inst. Past., *21*, 1907, 69.) From the human vagina.

Bacillus stellatus Vincent. (Vincent, Ann. Inst. Past., *21*, 1907, 62; not *Bacillus stellatus* Chester, Man. Determ. Bact., 1901, 274.) From water.

Bacillus symbiophiles Shottmuller. (Leitfaden f. d. klin. bakt. Kultur., Berlin, 1923.) From the blood in a case of puerperal fever.

Bacterium albarrani Jungano. (Compt. rend. Soc. Biol., Paris, *63*, 1907, 302.) From a case of cystitis.

Bacterium minutissimum Le Blaye and Guggenheim. (*Cocco-bacillus minutissimum gazogenes* Jacobson, Ann. Inst. Past., *22*, 1908, 300; Le Blaye and Guggenheim, Manuel Pratique de Diagnostic Bact., Viget Frères, 1914.) From intestines of infants.

Bacteroides splenomegaliae (Pinoy) Hauduroy et al. (*Synbacterium splenomegaliae* Pinoy, Compt. rend. Acad. Sci., Paris, *182*, 1926, 1429; Hauduroy et al.,

Dict. d. Bact. Path., 1937, 75.) From cases of splenomegaly in Algeria. Pathogenic.

Pasteurella anaerobiontica Levinthal. (Cent. f. Bakt., I Abt., Orig., *106*, 1928, 195.) From the naso-pharynx of man.

Streptobacillus gracilis Guillemot and Hallé. (Guillemot and Hallé, Arch. Méd. Exp. et Anat. Path., *16*, 1904, 598; *Bacteroides streptobacilliformis* Hauduroy et al., Dict. d. Bact. Path., 1937, 76.) From putrid pleurisies.

Genus II. **Fusobacterium** *Knorr.**

(Knorr, Cent. f. Bakt., I Abt., Orig., *87*, 1922, 536; *Fusiformis* Prévot and *Fusocillus* Prévot, Ann. Inst. Past., *60*, 1938, 300.)

Gram-negative, anaerobic rods, usually with tapering ends. Usually non-motile. Stain with more or less distinct granules.

The type species is *Fusobacterium plauti-vincenti* Knorr.

Key to the species of genus **Fusobacterium.**

I. Acid from maltose.
  A. No gas produced.
    1. *Fusobacterium plauti-vincenti.*
  B. Gas produced.
    2. *Fusobacterium biacutum.*

II. No acid from maltose.
  A. Disagreeable odor produced on cultivation.
    3. *Fusobacterium nucleatum.*
  B. No odor produced.
    4. *Fusobacterium polymorphum.*

1. **Fusobacterium plauti-vincenti** Knorr. (Knorr, Cent. f. Bakt., I Abt., Orig., *89*, 1923, 16; *Fusiformis plauti-vincenti* and *Fusiformis vincenti* Hauduroy et al., Dict. d. Bact. Path., 1937, 240.) Named for H. C. Plaut and for H. Vincent who studied diseases of the respiratory tract.

The relationships between this organism and the following have not been clearly established: *Fusiformis dentium* Hoelling, Arch. f. Protistenkunde, *19*, 1910, 240; *Bacillus fusiformis* Veillon and Zuber, Arch. de méd. expér., *10*, 1898, 517 (*Corynebacterium fusiforme* Lehmann and Neumann, Bakt. Diag., 4 Aufl., *2*, 1907, 529); not *Bacillus fusiformis* Gottheil, Cent. f. Bakt., II Abt., 7, 1901, 724; *Fusiformis fusiformis* Topley and Wilson, Princip. of Bact. and Immun., 1st ed., *1*, 1931, 300.

Weinberg, Nativelle and Prévot (Les Microbes Anaérobies, 1937, 804) and Prévot (Ann. Inst. Past., *60*, 1938, 285) make a distinction between Plaut's bacillus (*Fusocillus plauti*) and Vincent's bacillus (*Fusiformis fusiformis*), the former being actively motile and non-pathogenic and the latter non-motile and pathogenic.

Rods: 0.5 to 1.0 by 8 to 16 microns, occurring in pairs with blunt ends together and outer ends pointed, sometimes in short, curved chains or long spirillum-like threads. Granules present. Non-motile. Gram-negative.

Serum agar shake culture: After 36 hours, colonies spherical, up to 0.5 mm in diameter, thin, yellowish-brown.

Serum agar plate: Matted growth. Medium around colonies becomes turbid from the precipitation of protein. No surface growth.

Serum broth: Milky turbidity.

Liver broth: No turbidity. Grayish-white, flaky precipitate.

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* Arranged by Prof. Robert S. Breed, New York State Experiment Station, Geneva, New York, December, 1938; rearranged, December, 1945.

Indole not formed.

Acid from glucose, fructose, sucrose, maltose and sometimes from lactose. No acid from inulin or mannitol. (Hine and Berry, Jour. Bact., *34*, 1937, 524.)

No H_2S produced.

No odor produced.

No gas formed.

Non-pathogenic for white mice (Hauduroy et al., *loc. cit.*).

Temperature relations: Optimum 35° to 37°C. Minimum 30°C. (Hauduroy et al., *loc. cit.*)

Optimum pH 6.8 to 8.0 (Hauduroy et al., *loc. cit.*).

Anaerobe.

Source: Two strains isolated from deposit on teeth.

Habitat: Presumably the buccal cavity.

2. **Fusobacterium biacutum** Weinberg and Prévot. (Weinberg and Prévot, Compt. rend. Soc. Biol., Paris, *95*, 1926, 519; *Fusiformis biacutus* Hauduroy et al., Dict. d. Bact. Path., 1937, 238.) From Latin, double pointed.

Rods: 0.4 to 0.5 by 1.4 to 3.0 microns, with pointed ends, occurring singly, in pairs or sometimes in short chains. Non-motile. Gram-negative.

Gelatin: No liquefaction.

Veillon's agar: Rapid growth. Colonies lens-shaped. Gas is produced which breaks up the medium.

Plain broth: Poor growth.

Glucose broth: Turbid. Medium rapidly acidified. Good growth.

Indole not formed.

Milk: Acid and coagulation in 2 to 8 days. Curd not digested.

Casein and coagulated egg-white not digested.

Neutral red reduced.

Acid from glucose, fructose, galactose, maltose and lactose.

Small amount of H_2S produced.

Does not require blood serum for growth.

Pathogenic for guinea pigs.

Killed in 60 minutes at 60°C.

Anaerobic.

Source: Six strains isolated from a case of appendicitis.

Habitat: Unknown.

3. **Fusobacterium nucleatum** Knorr. (Knorr, Cent. f. Bakt., I Abt., Orig., *89*, 1923, 17; *Fusiformis nucleatus* Bergey et al., Manual, 3rd ed., 1930, 514.) Latinized, nucleated.

Rods: 1.0 by 4.0 microns, spindle-shaped, occurring singly. One or two granules present. Non-motile. Gram-negative.

Serum agar plate: Deep colonies lens-shaped with offshoots.

Plain liver broth: No growth.

Liver broth with serum: After 1 to 3 days, flocculent deposit on the pieces of liver.

Indole not formed (Knorr, *loc. cit.*). Indole formed (Hine and Berry, Jour. Bact., *34*, 1937, 521).

Disagreeable odor produced on cultivation.

No gas produced.

Acid from glucose, usually from fructose, sometimes from sucrose and lactose. No acid from maltose, inulin or mannitol. (Hine and Berry, *loc. cit.*)

No H_2S formed.

Temperature relations: Optimum 35° to 37°C. Minimum 30°C. (Hauduroy et al., Dict. d. Bact. Path., 1937, 239.) Survives 56°C for 15 minutes, but not 60°C for 10 minutes (Hine and Berry, *loc. cit.*).

Optimum pH 6.8 to 8.2 (Hauduroy et al., *loc. cit.*).

Anaerobe.

Source: One strain isolated from deposit on teeth in a healthy mouth.

Habitat: Presumably the buccal cavity.

4. **Fusobacterium polymorphum** Knorr. (Knorr, Cent. f. Bakt., I Abt., Orig., *89*, 1923, 19; *Fusiformis polymorphus* Bergey et al., Manual, 3rd ed., 1930, 515.) From Greek, assuming many forms.

Rods: 0.2 to 0.5 by 8 to 16 microns,

occurring in pairs with the pointed ends adjoining. Often occurring in threads. Non-motile. Gram-negative.

Serum agar plates (alkaline): After 2 to 3 days, colonies 0.5 mm or larger, lens-shaped with offshoots.

Tenacious sediment in liquid media.

Indole not formed (Knorr, *loc. cit.*). Indole formed (Hine and Berry, Jour. Bact., *34*, 1937, 522).

No gas produced.

No odor produced.

Acid usually produced from glucose, fructose, and sucrose. No acid from lactose, maltose, inulin or mannitol. (Hine and Berry, *loc. cit.*)

No H_2S produced.

Temperature relations: Optimum 35° to 37°C. Minimum 30°C. (Hauduroy et al., Dict. d. Bact. Path., 1937, 242.) Survives 50°C for 15 minutes, 52°C for 10 minutes and 56°C for 5 minutes (Hine and Berry, *loc. cit.*, 523).

Optimum pH 7.0 to 8.2 (Hauduroy et al., *loc. cit.*).

Anaerobe.

Source: One strain isolated from deposit on teeth in a case of gingivitis.

Habitat: Presumably the buccal cavity.

Appendix I: The following species are mentioned here because they appear to be related to the organisms in the genus *Fusobacterium*:

Bacillus hastilis Seitz. (Ztschr. f. Hyg., *30*, 1899, 47; *Mycobacterium hastilis* Chester, Man. Determ. Bact., 1901, 356.) A collective name for the organisms frequently found in stinking pus and in tonsillar pockets in both healthy and diseased mouths.

Fusocillus shmamini Prévot. (Ann. Inst. Past., *60*, 1938, 300.) Feebly motile.

Fusiformis acnes, *Fusiformis hodgkini* and *Fusiformis typhi-exanthematici* (Plotz) of Holland (Jour. Bact., *5*, 1920 223) are names presumably intended for bacteria more properly placed in the genus *Corynebacterium*.

Fusiformis muris Hoelling. (Arch. f. Protistenkunde, *19*, 1910, 239.) From the blind gut of a mouse. Stated by the author to be similar to *Fusiformis termitidis* Hoelling.

Fusiformis necrophorus Topley and Wilson. See *Spherophorus necrophorus* Prévot, page 578.

Fusiformis nodosus Beveridge. (Beveridge, Austral. Council Sci. and Indus. Res. Bul. 140, 1941, 56 pp.; *Actinomyces nodosus* Hagan, The Infectious Diseases of Domestic Animals. Ithaca, New York, 1943, 312.) Considered the primary cause of footrot of sheep. Also see *Spirochaeta penortha*.

Appendix II: Because of the preferable form of the name and also because it is questionable whether the anaerobic fusiform bacteria of the mouth closely resemble the more or less aerobic bacteria found in termites, the genus name *Fusobacterium* Knorr has been used for the mouth organisms. The termite organisms live in the intestinal tract bathed in digested wood and have the microscopic appearance of the cellulose-destroying *Cytophaga* Winogradsky. These are shown by Stanier (Jour. Bact., *40*, 1940, 619) to belong to *Myxobacteriales*.

The organisms placed in *Fusiformis* Hoelling are as follows:

Fusiformis hilli Duboscq and Grasse. (Arch. Zool. Expér. et Gén., *66*, 1927, 454 and 486.) Found as an ectoparasite on flagellates *Descovina spp.* which live in the rectum of termites (*Calotermes* (*Glyptotermes*) *iridipennis*).

Fusiformis termitidis Hoelling. (Arch. f. Protistenkunde, *19*, 1910, 239.) From the intestinal tract of termites.

TRIBE IV. HEMOPHILEAE WINSLOW ET AL.

(Jour. Bact., *5*, 1920, 212.)

Minute parasitic forms growing on first isolation only in the presence of hemoglobin, ascitic fluid or other body fluids, or in the presence of certain growth accessory substances found in sterile, unheated plant tissue (potato). Motile or non-motile. Commonly found in the mucosa of respiratory tract or conjunctiva.

Key to the genera of tribe **Hemophileae.**

I. Aerobes to facultative anaerobes.
  A. Non-motile.
    1. Predominantly occurring singly.
      Genus I. *Hemophilus*, p. 584.
    2. Predominantly occurring as diplobacilli.
      Genus II. *Moraxella*, p. 590.
  B. Motile, encapsulated.
      Genus III. *Noguchia*, p. 592.
II. Anaerobes.
  A. Non-motile.
      Genus IV. *Dialister*, p. 594.

Genus I. Hemophilus *Winslow et al.**

(Jour. Bact., *2*, 1917, 561.) From Greek, loving blood.

Minute rod-shaped cells, sometimes thread-forming and pleomorphic. Non-motile. Gram-negative. Strict parasites growing best (or only) in the presence of hemoglobin and in general requiring blood serum, ascitic fluid, or certain growth accessory substances.

The type species is *Hemophilus influenzae* (Lehmann and Neumann) Winslow et al.

Key to the species of genus **Hemophilus.**

I. Affecting the respiratory tract.
  1. Require both V and X growth factors for growth.
      1. *Hemophilus influenzae.*
      2. *Hemophilus suis.*
      3. *Hemophilus hemolyticus.*
  2. V growth factor sufficient for growth.
      4. *Hemophilus parainfluenzae.*
      5. *Hemophilus pertussis.*
II. Affecting the genital region.
  3. X growth factor sufficient for growth.
      6. *Hemophilus ducreyi.*
      7. *Hemophilus haemoglobinophilus.*

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* Revised by Dr. Margaret Pittman, National Institute of Health, Bethesda, Maryland, October, 1945.

Where the relationship to growth accessory factors is known, the following table may serve as a key:

Species	Growth in peptone water containing		
	Growth factor X	Phosphopyridine nucleotide (V)	Growth factors X and V
Hemophilus influenzae	−	−	+
Hemophilus suis	−	−	+
Hemophilus hemolyticus	−	±	+
Hemophilus parainfluenzae	−	+	+
Hemophilus haemoglobinophilus	+	−	+

1. **Hemophilus influenzae** (Lehmann and Neumann) Winslow et al. (Koch, Wiener med. Wchnschr., *33*, 1883, 1550; Weeks, New York Med. Record, *31*, 1887, 571; Influenzabacillus, Pfeiffer, Deutsche med. Wchnschr., 1892, 28; Ztschr. f. Hyg., *13*, 1893, 357; *Bacterium influenzae* Lehmann and Neumann, Bakt. Diag., 1 Aufl., *2*, 1896, 187; *Bacillus influenzae* Kruse, in Flügge, Die Mikroorganismen, 3 Aufl., *2*, 1896, 434; *Bacterium aegyptiacum* Lehmann and Neumann, Bakt. Diag., 2 Aufl., *2*, 1899, 191; *Hemophilus meningitidis cerebrospinalis septicemiae* Cohen, Ann. Inst. Past., *23*, 1909, 273; Winslow et al., Jour. Bact., *2*, 1917, 561; *Coccobacillus pfeifferi* Neveu-Lemaire, Précis Parasitol. Hum., 5th ed., 1921, 20; *Hemophilus conjunctivitidis* Bergey et al., Manual, 1st ed., 1923, 270.) From influenza, a disease of the respiratory tract.

Common name: The Koch-Weeks Bacillus.

Very small rods: 0.2 to 0.3 by 0.5 to 2.C microns, occurring singly and in pairs, occasionally in short chains, and at times long thread forms are seen. Frequently show a marked tendency to bipolar staining. Some strains are encapsulated. Non-motile. Gram-negative.

Requires both the factors X and V for its growth.

Gelatin colonies: No growth.

Gelatin stab: No growth.

Blood agar colonies: Small, circular, transparent, homogeneous, entire. Satellitism with *Staphylococcus*.

Blood agar slant: Thin, filiform, transparent growth.

Chocolate agar slant: Luxuriant growth.

Blood broth: Slightly turbid. No hemolysis.

Litmus milk, with blood: Some strains render it very slightly alkaline.

Sterilized potato slant: No growth.

Fresh unheated sterile potato added to broth favors development.

Indole is formed by some strains.

Nitrites are produced from nitrates.

Some strains attack none of the carbohydrates, while other strains attack various carbohydrates, provided a suitable medium is used. Mannitol and lactose never fermented.

Pathogenic.

Aerobic, facultative.

Optimum temperature 37°C. Maximum 43°C. Minimum 26° to 27°C. Killed at 55°C for thirty minutes.

Source: Isolated by Pfeiffer in cases of influenza. Found in conjunctiva, nasopharynx, sputum, sinuses, cerebrospinal fluid, blood, and pus from joints.

Habitat: Respiratory tract. A cause of acute respiratory infections, of acute conjunctivitis, and of purulent meningitis of children, rarely of adults. Re-

garded by Pfeiffer and others to be the cause of influenza.

NOTE: Six types (a–f) of *Hemophilus influenzae* are recognized on the basis of precipitation of immune serum by capsular substance. Strains from cerebrospinal fluid are usually of type b. The majority of the strains from the respiratory tract are not type-specific.

2. **Hemophilus suis** Hauduroy et al. (*Hemophilus influenzae suis* Lewis and Shope, Jour. Exp. Med., *54*, 1931, 361 and 373; *Bacterium influenzae suis* Kobe, Cent. f. Bakt., I Abt., Orig., *129*, 1933, 161; Hauduroy et al., Dict. d. Bact. Path., 1937, 258.) From Latin, swine.

Resembles *Hemophilus influenzae* except it is relatively inert to growth, indole is not formed, nitrites are produced from nitrates, and maltose and sucrose are slightly fermented but not the carbohydrates fermented by *Hemophilus influenzae*.

Source: From cases of swine influenza.

Habitat: With a filterable virus it causes swine influenza.

3. **Hemophilus hemolyticus** Bergey et al. (Bacillus X, Pritchett and Stillman, Jour. Exp. Med., *29*, 1919, 259; Stillman and Bourn, Jour. Exp. Med., *32*, 1920, 665; Bergey et al., Manual, 1st ed., 1923, 269.) From Greek, blood-dissolving.

Morphologically like *Hemophilus influenzae*. Non-motile. Gram-negative.

Requires both the factors X and V for its growth. Valentine and Rivers (Jour. Exp. Med., *45*, 1927, 993) isolated certain hemolytic strains which did not entirely agree with this.

Blood agar colonies: Resemble *Hemophilus influenzae* but surrounded by a zone of hemolysis.

Blood agar slant: Thin, filiform, transparent growth.

Blood broth: Turbid, showing hemolysis.

Blood milk mixture: Slightly alkaline.

Sterile unheated potato favors development.

Indole is formed by some strains.

Nitrites are produced from nitrates.

Some strains do not attack carbohydrates, other strains ferment various carbohydrates.

Aerobic, facultative.

Optimum temperature 37°C.

Habitat: Found in upper respiratory tract of man. Non-pathogenic.

4. **Hemophilus parainfluenzae** Rivers. (Johns Hopkins Hosp. Bull., *33*, 1922, 429.) From Latin, like, and the disease, influenza.

Morphologically like *Hemophilus influenza*. Non-motile. Gram-negative.

Requires the V factor for its growth.

Blood agar colonies: Resemble *Hemophilus influenzae*. No hemolysis.

Blood agar slant: Thin filiform transplant.

Broth containing yeast extract: Floccular sediment.

Indole is formed by some strains from cat.

Nitrites are produced from nitrates.

Some strains attack none of the carbohydrates; other strains ferment various carbohydrates.

Aerobic, facultative.

Optimum temperature 37°C.

Habitat: Found in upper respiratory tract of man and cat. Usually non-pathogenic.

5. **Hemophilus pertussis** Holland. (Microbe de coqueluche, Bordet and Gengou, Ann. Inst. Past., *20*, 1906, 731; Holland, Jour. Bact., *5*, 1920, 219; *Bacillus pertussis* Holland, *idem*; *Bacterium tussis convulsivae* Lehmann and Neumann, Bakt. Diag., 7 Aufl., *2*, 1927, 317 (Bordet and Gengou's organism); not *Bacterium tussis convulsivae* Lehmann and Neumann, Bakt. Diag., 2 Aufl., *2*, 1899, 192 (Czaplewski and

Hensel's organism).) From Latin, whooping cough.

Short, oval rods: 0.2 to 0.3 by 1.0 micron, occurring singly or sometimes in pairs and short chains. Show tendency to bipolar staining. Capsules may be demonstrated by special technic (Lawson). Non-motile. Gram-negative.

No growth on the usual laboratory media; adapted by repeated transfer with heavy inoculum. Adaptation accompanied by loss of original characteristics.

Bordet-Gengou medium or some modification containing at least 15 per cent blood is optimum for isolation and maintenance.

Colonies: Smooth, raised, entire, pearly, glistening. Surrounded by a zone of hemolysis.

Litmus milk: (After adaptation) brownish color. Alkaline.

Indole not formed.

Nitrites not produced from nitrates.

No action in carbohydrate media.

Catalase positive.

Aerobic.

Optimum temperature 37°C.

Serologically homogeneous when first isolated (Phase I of Leslie and Gardner). Dissociative changes, recognizable morphologically, culturally, antigenically, and by animal tests, take place when maintained on unfavorable media.

Source: From respiratory tract in cases of whooping cough, especially by the cough plate method.

Habitat: Etiologically associated with whooping cough.

NOTE: *Bacillus para-pertussis* Eldering and Kendrick. (Jour. Bact., *35*, 1938, 561.) From cases of whooping-cough. Closely related antigenically to *Hemophilus pertussis* and *Brucella bronchiseptica*, but distinct from either.

6. Hemophilus ducreyi (Neveu-Lemaire) Bergey et al. (Ducrey, Cong. internat. de dermatol. et syph., Compt. rend., Paris, 1890, 229; Monatshft. f. prakt. Dermatol., *9*, 1889, 387; Riforma med., *5*, 1889, 98; Monatshft. f. prakt. Dermatol., *21*, No. 2; Streptobacillus of soft chancre, Ducrey, Abstract in Cent. f. Bakt., I Abt., *18*, 1895, 290; *Bacillus ulceris cancrosi* Kruse, in Flügge, Die Mikroorganismen, 3 Aufl., *2*, 1896, 456; *Bacterium ulceris cancrosi* Chester, Ann. Rept. Del. Col. Agr. Exp. Sta., *9*, 1897, 67; *Bacterium cancrosi* Chester, Manual Determ. Bact., 1901, 120; *Coccobacillus ducreyi* Neveu-Lemaire, Précis Parasitol. Hum., 5th ed., 1921, 20; Bergey et al., Manual, 1st ed., 1923, 271.) Named for Ducrey who first isolated the organism.

Small rods: 0.5 by 1.5 to 2.0 microns, with rounded ends, occurring singly and in short chains. Non-motile. Gram-negative.

Requires the X factor for its growth.

Gelatin colonies: No growth.

Gelatin stab: No growth.

Blood agar colonies: Small, grayish, glistening, showing a slight zone of hemolysis around the colony in three or four days.

Best growth is obtained on clotted rabbit, sheep, or human blood heated to 55°C for 15 minutes, and in casein digest agar containing blood. Moisture is important for growth.

Aerobic, facultative.

Optimum temperature 37°C.

Habitat: The cause of soft chancre (chancroid).

7. Hemophilus haemoglobinophilus (Lehmann and Neumann) Murray. (*Bacillus haemoglobinophilus canis* Friedberger, Cent. f. Bakt., I Abt., Orig., *33*, 1903, 401; *Bacterium haemoglobinophilus* Lehmann and Neumann, Bakt. Diag., 4 Aufl., *2*, 1907, 270; *Hemophilus canis* Rivers, Johns Hopkins Bull., *33*, 1922, 149; Jour. Bact., *7*, 1922, 579; Murray, in Manual, 5th ed., 1939, 309.) From Greek, hemoglobin-loving.

Small rods: 0.2 to 0.3 by 0.5 to 2.0 microns, occurring singly, in pairs and

short chains. Non-motile. Gram-negative.

Requires the X factor for its growth.

Blood agar colonies: Small, clear, transparent, entire. Old colonies become opaque.

Blood broth: Turbid.

Blood milk mixture: Doubtful development.

Indole is formed.

Nitrites produced from nitrates.

Acid but no gas from glucose, fructose, galactose, mannitol, sucrose and xylose. No acid from maltose, lactose dextrin, arabinose or glycerol. (Rivers, *loc. cit.*)

Optimum temperature 37°C.

Aerobic, facultative.

Habitat: Occurs in large numbers in preputial secretions of dogs.

Appendix I:* The following species has been placed in the tribe *Hemophileae* by Van Rooyen (Jour. Path. and Bact., *43*, 1936, 469). It has been pointed out by Buchanan (General Systematic Bacteriology, 1925, 490) that the genus name *Streptobacillus* is invalid.

Streptobacillus moniliformis Levaditi, Nicolau and Poincloux. (Compt. rend. Acad. Sci., Paris, *180*, 1925, 1188.)

This organism is regarded as identical with *Haverhillia multiformis* Parker and Hudson (Amer. Jour. Path., *2*, 1926, 357) by Van Rooyen (*loc. cit.*). Topley and Wilson (Princip. Bact. and Immun., 2nd ed., 1936, 270) regard it as identical with their *Actinomyces muris* (*Streptothrix ratti* Schottmüller), the cause of rat-bite fever. *Asterococcus muris* Heilman, Jour. Inf. Dis., *69*, 1941, 32. See *Actinomyces muris ratti* in the Appendix to the genus *Streptomyces*. Jordan and Burrows (Textb. of Bact., 14th ed., 1946, 614) consider all these names synonymous. Dawson and Hobby (Proceedings, Third Internat. Congr. for Microbiol., New York, 1940, Section I, 177) suggest that the pleuropneumonia-like cultures isolated from *Streptobacillus moniliformis* really represent variant phases in the growth of this organism.

Description from Levaditi et al. (*loc. cit.*) and Brown and Nunemaker (Bull. Johns Hopkins Hosp., *70*, 1942, 201).

Streptobacilli: 2.0 to 3.0 microns in length, pleomorphic, with branching filaments up to 30 to 40 microns long, fragmented, bacillary and coccobacillary forms. Swollen and club-shaped cells are found. Morphology is best demonstrated by aniline dyes, e.g. Wayson's plague stain. Non-motile. Gram-negative.

Enriched media are required for good growth. Best liquid media are rabbit blood and broth containing serum or ascitic fluid. Best solid media are glycerol extract of potato-infusion broth-egg yolk medium and nutrient agar containing serum.

Blood agar or ascitic serum agar: Colonies small, clear.

Blood plates: Growth slow. Numerous small whitish colonies appear on the third day.

Veillon's medium: Punctiform colonies, abundant in depth, less growth at surface. No gas.

Broth with ascitic fluid and globular extract: Good growth, forming clots which precipitate and are rather adherent to one another. Growth rapidly reduces the pH of the medium killing the bacteria in cultures 24 hrs. old.

Milk: Slow growth. No coagulation.

Löffler's serum: Poor growth.

Virulent for rabbits and mice.

Good growth at 37°C.

Facultative anaerobe. Grows better under anaerobic conditions in the presence of added CO_2, than in the presence of air.

Source: Isolated from a case of a febrile,

* Appendixes I and II arranged by Prof. E. G. D. Murray, McGill Univ., Montreal, P. Q., Canada, March, 1946.

septicemic disease, accompanied by arthritis, erythema and angina.

Habitat: The cause of an acute febrile disease sometimes called erythema multiforme.

Appendix II: The following species may be identical with some of those listed above or related to them:

Bacillus marianensis Leber and Prowazek. (Berlin. klin. Wochnschr., *1*, 1911, 27.) Allied to the Koch-Weeks Bacillus. Associated with cases of pink eye.

Bacillus weeksi Neveu-Lemaire. (Précis Parasitol. Hum., 5th ed., 1921, 24.) Described by Weeks. The cause of trachoma or granular conjunctivitis in tropical countries. Transmitted by the domestic fly. Probably intended for the Week's bacillus (Weeks, New York Med. Record, *31*, 1887, 571).

Bacterium tussis convulsivae Lehmann and Neumann. (Bacterium, Czaplewski and Hensel, Deut. med. Wochnschr., *23*, 1897, 587; Lehmann and Neumann, Bakt. Diag., 2 Aufl., *2*, 1899, 192; not *Bacterium tussis convulsivae* Lehmann and Neumann, *ibid.*, 7 Aufl., *2*, 1927, 317; *Bacillus tussis convulsivae* Lehmann and Neumann, *ibid.*, 4 Aufl., *2*, 1907, 269.) Considered the cause of whooping cough by the original isolators.

Hemophilus aphrophilus Khairat. (Jour. Path. and Bact., *50*, 1940, 497.) From blood and from heart valve of a case of endocarditis.

Hemophilus cuniculi Hauduroy et al. (*Hemophilus sp.* Gibbons, Jour. Inf. Dis., *45*, 1929, 288; Hauduroy et al., Dict. d. Bact. Path., 1937, 249.) From skin abscesses of rabbits.

Hemophilus gallinarum Delaplane, Erwin and Stuart and *Hemophilus gallinarum* Eliot and Lewis. (*Bacillus hemoglobinophilus coryzae gallinarum* De Blieck, Tijdsch. v. Diergeneensk., *58*, 1931, 310; also see Vet. Jour., *88*, 1932, 9; Delaplane, Erwin and Stuart, R. I. State Coll. Sta. Bull. 244, May, 1934; Eliot and Lewis, Jour. Amer. Vet. Med. Assoc., *84*, 1934, 878.) From edematous fluid from the head of a chicken. The cause of an infectious rhinitis in chickens.

Hemophilus influenzae murium (Kairies and Schwartzer) Lwoff. (*Bacterium influenzae murium* Kairies and Schwartzer, Cent. f. Bakt., I Abt., Orig., *137*, 1936, 351; Lwoff, Ann. Inst. Past., *62*, 1939, 168.) From the lung of a mouse.

Hemophilus meningitidis (Martins) Hauduroy et al. (*Coccobacillus meningitidis* Martins, Compt. rend. Soc. Biol., Paris, *99*, 1928, 955; Hauduroy et al., Dict. d. Bact. Path., 1937, 254.) Resembles *Hemophilus influenzae* except that it shows sluggish motility. From cerebro-spinal fluid.

Hemophilus muris Hauduroy et al. (Bacillus of an epizootic of stock mice, Mackie, Van Rooyne and Gilroy, Brit. Jour. Exp. Path., *14*, 1933, 132; Hauduroy et al., Dict. d. Bact. Path., 1937, 255.) From heart blood, spleen and other organs of mice dying from an epizootic disease.

Hemophilus ovis Mitchell. (Jour. Amer. Vet. Assoc., *68*, 1925, 8.) From bronchi of sheep.

Hemophilus pertussis Ford. (*Bacillus pertussis eppendorf* Jochmann and Krause, Ztschr. f. Hyg., *36*, 1901, 193; Ford, Textb. of Bact., 1927, 615; not necessarily identical with Bordet and Gengou's organism, *Hemophilus pertussis* Holland, Jour. Bact., *5*, 1920, 215.) From the respiratory tract and lungs in pertussis.

Hemophilus putoriorum Hauduroy et al. (*Bacterium influenzae putoriorum multiforme* Kairies, Ztschr. f. Hyg., *117*, 1935, 12; Hauduroy et al., Dict. d. Bact. Path., 1937, 258.) From the respiratory tract of ferrets.

Lehmann and Neumann (Bakt. Diag., 6 Aufl., *2*, 1920, and 7 Aufl., *2*, 1927) list

the following species as closely related to this group:

Bacillus catarrhalis Jundell. (Hygieae, *60*, No. 6 and 7, p. 667.) From cases of acute bronchitis.

Bacillus trachomatis Lehmann and Neumann. (The Bacillus Müller, Luerssen, Cent. f. Bakt., I Abt., Orig., *39*, 1905, 682.) From conjunctiva.

Bacterium czaplewskii Chester. (Bacillus bei Keuchhusten, Czaplewski, Cent. f. Bakt., *22*, 1897, 641; *Bacterium tussis convulsivae* Lehmann and Neumann, Bact. Diag., 2 Aufl., 1899, 192; Chester, Man. Determ. Bact., 1901, 153.) From sputum in whooping cough. This is not now regarded as being etiologically associated with whooping cough.

Bacterium exiguum Stäubli. (Münch. med. Wchnschr., No. 45, 1905.) From a case of septic endocarditis.

Bacterium microbutyricum Hellstein. From butter.

Bacterium minutissimus sputi (Luzzatto) Lehmann and Neumann. (*Bacillus minutissimus sputi* Luzzatto, Cent. f. Bakt., I Abt., *27*, 1900, 816.) From a case of pertussis.

Bacterium polymorphum convulsivum Melfi. (Cent. f. d. gesamte Hygiene, *7*, 1924, 133.)

Bacterium septicaemiae canis Paranhos. (Cent. f. Bakt., I Abt., Orig., *50*, 1909, 607.)

Streptobacillus urethrae Pfeiffer. (Cent. f. Bakt., I Abt., Ref., *36*, 1905, 59.) From the normal urethra and from cases of chronic cystitis and urethritis.

Genus II. Moraxella *Lwoff.**

(*Diplobacillus* McNab, Klinische Monatsbl. f. Augenheilk., *42*, 1904, 64; not *Diplobacillus* Weichselbaum, Cent. f. Bakt., *2*, 1887, 212; Lwoff, Ann. Inst. Past., *62*, 1939, 168.) Named for Morax, who first isolated the type species.

Small, short, rod-shaped cells, usually occurring singly or in pairs. Non-motile. Parasitic. Aerobic. Gram-negative.

The type species is *Moraxella lacunata* (Eyre) Lwoff.

Key to the species of genus **Moraxella.**

I. No growth in gelatin.
   1. *Moraxella lacunata.*

II. Gelatin liquefied.
   A. Rapid liquefaction. No growth in milk.
      2. *Moraxella liquefaciens.*
   B. Very slow liquefaction. Cells capsulated. Growth in milk.
      3. *Moraxella bovis.*

1. **Moraxella lacunata** (Eyre) Lwoff. (Diplobacille de la conjunctivite subaigue, Morax, Ann. Inst. Past., *10*, 1896, 337; Diplobacillus of chronic conjunctivitis, Axenfeld, Cent. f. Bakt., I Abt., *21*, 1897, 1; *Bacterium conjunctivitis* Chester, Ann. Rept. Del. Col. Agr. Exp. Sta., *9*, 1897, 85; *Bacillus lacunatus* Eyre, Jour. Path. and Bact., *6*, 1899, 1; not *Bacillus lacunatus* Wright, Memoirs Nat. Acad. Sci., *7*, 1895, 435; *Diplobacillus moraxaxenfeld* McNab, Klinische Monatsbl. f. Augenheilk., *42*, 1904, 64; *Bacterium duplex* Lehmann and Neumann, Bakt. Diag., 2 Aufl., *2*, 1899, 193; *Hemophilus lacunatus* Holland, Jour. Bact., *5*, 1920, 223; *Bacillus duplex* Hewlett, Med. Res. Council Syst. of Bact., *2*, 1929, 417;

* **Arranged by Prof. E. G. D. Murray, McGill University, Montreal, P. Q., Canada, September, 1945.**

Lwoff, Ann. Inst. Past., *62*, 1939, 173; *Hemophilus duplex* Murray, in Manual, 5th ed., 1939, 308.) From Latin, pitted.

Audureau (Ann. Inst. Past., *64*, 1940, 128) recognizes an atypical variety of this species. To distinguish between the two varieties, she designates these as *Moraxella lacunata* var. *typica* and *Moraxella lacunata* var. *atypica*.

Short rods: 0.4 to 0.5 by 2.0 microns, occurring singly and in pairs and short chains. Ends rounded or square in the chains. Non-motile. Gram-negative.

Gelatin colonies: No growth.

Gelatin stab: No growth.

Blood agar colonies: Small, circular, transparent, entire. Growth on subculture difficult. Certain strains are not surrounded by zones of hemolysis; others are (Oag, Jour. Path. and Bact., *54*, 1942, 128).

Serum agar colonies: Delicate, grayish.

Löffler's blood serum: Slow but definite liquefaction (pitting) around the colonies.

Ascitic broth: Turbid with slight, grayish sediment.

Blood milk mixture: Doubtful development.

Litmus milk: Unchanged.

Potato: No growth.

Indole not formed.

Nitrites not produced from nitrates.

Various carbohydrates and mannitol are attacked.

Optimum temperature 37°C.

Aerobic, facultative.

Source: From conjunctiva.

Habitat: The cause of subacute infectious conjunctivitis, or angular conjunctivitis.

2. **Moraxella liquefaciens** (McNab) *comb. nov.* (Diplobacille liquéfiant, Pettit, Annales d'oculistique, March, 1899, 166 and Thesis, Paris, 1900, 223; *Diplobacillus liquefaciens* McNab, Klinische Monatsbl. f. Augenheilk., *42*, 1904, 64; *Bacillus duplex liquefaciens* Lwoff, Ann. Inst. Past., *62*, 1939, 170; *Moraxella duplex liquefaciens* Lwoff, *ibid.*, 171; *Moraxella duplex* Lwoff, *ibid.*, 171; *Moraxella duplex* var. *liquefaciens* Audureau, Ann. Inst. Past., *64*, 1940, 139.) From Latin, liquefying.

Diplobacilli: 1.0 to 1.5 by 2.0 microns, occurring singly and in pairs, and having rounded ends. Capsules not demonstrated. Non-motile. Stain uniformly with basic aniline dyes. Gram-negative.

Gelatin colonies: Round, 1.5 to 2.0 mm in diameter, yellowish-white.

Gelatin stab: Rapid liquefaction.

Blood agar: Ready growth in primary and subculture.

Ascitic agar colonies: Grayish, thick, round, viscous.

Peptone agar colonies: Same as above, but less abundant growth.

Coagulated serum: Liquefaction in 3 to 4 days; eventually complete.

Plain broth: Poor growth, if any. Slight uniform turbidity.

Ascitic broth: Abundant growth in 24 hours at 35°C. Uniform turbidity. Later sediment and an opaque pellicle.

Milk: No growth. No coagulation.

Potato: Slight, yellowish-white, viscous growth.

Optimum temperature between 20° and 37°C. Killed at 55°C for 15 minutes.

Aerobic.

Not pathogenic for laboratory animals.

Source: From cases of conjunctivitis associated with corneal ulceration in man.

Habitat: Conjunctivitis in man so far as known.

3. **Moraxella bovis** (Hauduroy et al.) *comb. nov.* (Diplobacillus, Allen, Jour. Amer. Vet. Med. Assn., *54*, 1918, 307; Diplobacillus, Jones and Little, Jour. Exp. Med., *38*, 1923, 139; *Hemophilus bovis* Hauduroy et al., Dict. d. Bact. Path., 1937, 247; *Moraxella duplex* des Bovidés, Lwoff, Ann. Inst. Past., *62*, 1939, 174; *Hemophilus ruminantium* Reid and Anigstein, Texas Reports on

Biol. and Med., *3*, 1945, 187.) From Latin *bovis*, of the ox.

Short, plump rods: 0.5 by 1.5 to 2.0 microns, usually occurring in pairs and short chains, with rounded ends. Capsulated. Non-motile. Gram-negative.

Gelatin: Slow growth at 22°C. Very slow liquefaction.

Blood agar colonies: After 24 hours, round, translucent, grayish-white, surrounded by a narrow, clear zone of hemolysis. Deep colonies tiny with a clear hemolytic zone, usually 1.5 mm in diameter. After 48 hours, surface colonies somewhat flattened, 3.5 to 4 mm in diameter; deep colonies ellipsoidal and biconvex with hemolytic area of 2.5 to 3 mm in diameter.

Blood agar slants: After 24 hours at 38°C, heavy, viscid, grayish-white growth.

Coagulated serum liquefied.

Broth: Slow growth. Slight turbidity. Considerable sediment.

Litmus milk: Alkaline. Partial coagulation.

Indole not produced.

Potato: No growth.

No acid from glucose or other carbohydrates.

Not pathogenic for laboratory animals.

Killed at 58° to 59°C in five minutes.

Aerobic.

Source: From cases of acute ophthalmia (pink eye) of cattle.

Habitat: In the exudate from cases of acute ophthalmia of cattle. The probable cause of bovine infectious keratitis (Baldwin, Amer. Jour. Vet. Res., *6*, 1945, 180).

Appendix: Other species placed in the genus *Moraxella* are as follows:

Moraxella josephi Lwoff. (*Bacillus duplex josephi* Scarlett, Annales d'Oculistique, *153*, 1916, 100 and 485; Lwoff, Ann. Inst. Past., *62*, 1939, 171; *Moraxella duplex josephi* Lwoff, *ibid.*, 174; *Bacillus josephi* Audureau, Ann. Inst. Past., *64*, 1940, 126.) Gram-positive. Pathogenic. From the conjunctiva of man.

Moraxella lwoffi Audureau. (Ann. Inst. Past., *64*, 1940, 150.) Two varieties are recognized: var. *bacteroides* and var. *brevis*. From various types of conjunctivitis in man.

Moraxella non liquefaciens Lwoff. (*Bacterium duplex-nonliquefaciens* Oliver and Wherry, Jour. Inf. Dis., *28*, 1921, 342; *Bacillus duplex non-liquefaciens* Hewlett, Med. Res. Council Syst. of Bact., *2*, 1929, 418; Lwoff, Ann. Inst. Past., *62*, 1939, 171; *Moraxella duplex non liquefaciens* Lwoff, *ibid.*, 174; *Bacillus duplex non liquefaciens* Audureau, Ann. Inst. Past., *64*, 1940, 126; *Moraxella duplex* var. *non liquefaciens* Audureau, *ibid.*, 144.) From an ulcer of the cornea, and from bronchial sputum in man.

Genus III. **Noguchia** *Olitsky, Syverton and Tyler.**

(Jour. Exp. Med., *60*, 1934, 382.) Named for Noguchi, the bacteriologist who isolated the type species.

Small, slender, Gram-negative rods present in the conjunctiva of man and animals affected by a follicular type of disease; mucoid type of growth which on first isolation takes place with some difficulty in ordinary media; motile, flagellated, and encapsulated; aerobic and facultative anaerobic; optimum temperature for growth 28° to 30°C.

The type species is *Noguchia granulosis* (Noguchi) Olitsky, Syverton and Tyler.

Key to the species of genus **Noguchia.**

I. Acid from carbohydrates.
  A. Acid from raffinose, maltose and salicin.
    1. *Noguchia granulosis.*

* Arranged by Prof. C. D. Kelly, McGill University, Montreal, October, 1938.

B. No acid from raffinose, maltose and salicin.

2. *Noguchia simiae.*

II. No acid from carbohydrates.

3. *Noguchia cuniculi.*

1. **Noguchia granulosis** (Noguchi) Olitsky et al. (*Bacterium granulosis* Noguchi, Jour. Exp. Med., *48*, Supp. 2, 1928, 21; Olitsky, Syverton and Tyler, Jour. Exp. Med., *60*, 1934, 382.) From Latin, granular.

Rods: 0.25 to 0.3 by 0.8 to 1.2 microns, motile by means of a single flagellum, usually polar. Pleomorphic. Gram-negative.

No growth on plain agar or broth.

Blood agar plate: Minute round colonies, shiny, somewhat raised, almost transparent or slightly grayish in 48 hours. Later the colonies increase in size, are grayish opalescent and somewhat sticky. Old colonies have a brownish or yellowish tint.

Semi-solid *Leptospira* medium: Grayish-white, diffuse growth, forming a delicate zone 1 cm deep.

Liquid *Leptospira* medium: Diffuse, slightly cloudy growth, with sticky grayish sediment at the bottom of the tube in old cultures.

Acid from glucose, fructose, mannose, sucrose, galactose, maltose, salicin, xylose, mannitol, dextrin, arabinose, amygdalin and lactose. Small amount of acid from raffinose, inulin, rhamnose and trehalose. No acid from dulcitol, sorbitol and inositol.

Non-pathogenic for rabbits, guinea pigs, rats and mice.

Optimum pH 7.8.

Temperature relations: Optimum 15° to 30°C. Grows at 37°C.

Aerobe, facultative anaerobe.

Distinctive characters: Action on carbohydrates; agglutination reactions; motility at 15°, none at 37°C.

Source: From trachoma of American Indians at Albuquerque, New Mexico.

Habitat: Regarded by Noguchi and others as a cause of trachoma in man. Produces a granular conjunctivitis in monkeys and apes.

2. **Noguchia simiae** Olitsky et al. (*Bacterium simiae* Olitsky, Syverton and Tyler, Jour. Exp. Med., *57*, 1933, 875; Olitsky et al., Jour. Exp. Med., *60*, 1934, 382.) From Latin *simia*, ape.

Slender rods: 0.2 to 0.3 by 0.8 to 1.2 microns, occurring singly, in pairs, in short chains or parallel arrangement of two or three, having pointed ends. Capsules are found. Actively motile by means of a single, rarely a double, flagellum, usually polar. Gram-negative.

Gelatin plates: Colonies more mucoid and raised than on agar.

Gelatin stab: Arachnoid growth along line of inoculation. No liquefaction.

Agar plates: Small, circular, grayish, translucent, smooth, convex, slightly raised colonies having a sticky or mucoid consistency.

Blood agar plates: More highly translucent and colorless in early growth than on plain agar, becoming grayish after two or three days.

Agar slants: Grayish-white to white, moist, mucoid, raised, glistening growth. Growth is more profuse when blood is added.

Leptospira medium: Homogeneous, dense growth in a 0.5 cm sharply defined layer, with a slight, nebulous, uniform opacity about 1 cm below. In three or four days the lower layer becomes more dense and in time extends to the bottom of the tube.

Broth: Uniform turbidity, with a slight grayish sediment and no pellicle.

Litmus milk: Unchanged.

Potato: Light tan, spreading, abundant growth.

Indole not formed.

Nitrites not produced from nitrates.

Acid but no gas from glucose, fructose,

mannose, galactose, xylose, arabinose and rhamnose. Small amount of acid from dextrin. Some strains produce a small amount of acid from sucrose, lactose, inulin and mannitol. Raffinose, salicin, dulcitol, amygdalin, maltose, trehalose, sorbitol and inositol unchanged.

Serological reactions: Rabbit antiserum is specific for all strains and no cross agglutination with *Noguchia granulosis*.

Temperature relations: Optimum 28° to 30°C. Thermal death point 56°C for thirty minutes.

Aerobe, facultative anaerobe.

Distinctive characters: Action on carbohydrates; agglutination reactions.

Source: From inflammatory type (Type II) of spontaneous conjunctival folliculosis in *Macacus rhesus* monkeys.

Habitat: Causes conjunctival folliculosis in *Macacus rhesus* monkeys.

3. **Noguchia cuniculi** Olitsky, Syverton and Tyler. (Jour. Exp. Med., *60*, 1934, 382.) From Latin *cuniculus*, rabbit.

Slender rods: 0.2 to 0.3 by 0.5 to 1.0 micron with pointed ends. Capsules are formed of much finer texture than those surrounding *Noguchia granulosis* or *Noguchia simiae*. Actively motile with peritrichous flagella. Non-acid-fast. Pleomorphic forms sometimes noted. Gram-negative.

Gelatin agar plates: Grayish, mucoid and confluent colonies.

Gelatin stab: Tenuous, arborescent, non-spreading growth. No liquefaction.

Agar plates: Small, spherical, translucent, slightly grayish, smooth, somewhat convex, moist and mucoid colonies with entire edges.

Blood agar plates: More profuse, more grayish and less translucent than on plain agar.

Agar slants: Slightly grayish, translucent, coalescent, glistening, mucoid, homogeneous and non-spreading growth. The water of syneresis appears uniformly cloudy or milky depending on amount of growth.

Leptospira medium: After 24 hours, a faint, nebulous surface growth followed by an ingrowing sac-like mass, with its base 5 mm across, lying at the center of the under surface and extending for 5 mm into the medium. The area spreads laterally until at about two or three days there is a uniform, opaque, whitish layer about 1 cm thick which progresses slowly until the bottom of the tube is reached in about seven days.

Broth: Uniform turbidity, without pellicle.

Litmus milk: Unchanged.

Potato: Faint, buff-colored (changing to brown after five days), non-spreading, sparse surface growth.

Indole not produced.

Nitrites not produced from nitrates.

No acid or gas from glucose, fructose, mannose, mannitol, sucrose, raffinose, inulin, galactose, maltose, salicin, xylose, dextrin, arabinose, amygdalin, lactose, dulcitol, rhamnose, trehalose, sorbitol or inositol.

Serological relations: Rabbit antiserum is specific for all strains, and no cross agglutination with *Noguchia granulosis* or *Noguchia simiae*.

Temperature relations: Optimum 28° to 30°C. Thermal death point 56°C for 15 to 30 minutes.

Aerobe, facultative anaerobe.

Distinctive characters: No action on carbohydrates; peritrichous flagella; agglutination.

Source: From spontaneous conjunctival folliculosis, Type II of rabbits.

Habitat: Causes conjunctival folliculosis in rabbits.

Genus IV. Dialister *Bergey et al.**

(Manual, 1st ed., 1923, 271.)

Minute rod-shaped cells, occurring singly, in pairs and short chains. Non-motile.

* Rearranged by Prof. D. H. Bergey, Philadelphia, Pennsylvania, 1933.

Strict parasites. Growth occurs only under anaerobic conditions in media containing fresh, sterile tissue or ascitic fluid.

The type species is *Dialister pneumosintes* (Olitsky and Gates) Bergey et al.

1. **Dialister pneumosintes** (Olitsky and Gates) Bergey et al. (*Bacterium pneumosintes* Olitsky and Gates, Jour. Exp. Med., *33*, 1921, 713; *ibid.*, *35*, 1922, 813; Bergey et al., Manual, 1st ed., 1923, 271; *Bacillus pneumosintes* Ford, Textb. of Bact., 1927, 634.) From Greek *pneumon*, lung and *sintor*, murderer or devastator.

Very short rods: 0.15 to 0.3 (in glucose broth 0.5 to 1.0) micron in length, occurring singly and occasionally in pairs, short chains or masses. The ends are rather pointed. Non-motile. Gram-negative.

Blood agar colonies: Small, clear, circular, entire, translucent.

Growth occurs in media containing fresh sterile rabbit kidney and ascitic fluid. Under strict anaerobic conditions good growth on rabbit blood glucose agar plates.

Glucose broth in which *Escherichia coli* or *Bacillus mesentericus* (non-spore stage) has grown favors growth.

Acid but no gas from glucose. Neither acid nor gas from maltose, lactose, sucrose, inulin or mannitol.

Passes Berkefeld V and N filters.

Optimum pH 7.4 to 7.8. No growth at pH 7.0 or pH 8.0.

Optimum temperature 37°C. Does not survive 56°C for half an hour.

Pathogenic for rabbits and guinea pigs.

Strict anaerobe.

Source: From filtered nasopharyngeal secretions from influenza patients in the early hours of the disease.

Habitat: Nasopharyngeal washings of man.

2. **Dialister granuliformans** (Pavlovic) Bergey et al. (*Bacterium granuliformans* Pavlovic, Cent. f. Bakt., I Abt., Orig., *112*, 1929, 432; Bergey et al., Manual, 4th ed., 1934, 341.) From Latin, forming granules.

Small rods: Non-motile. Gram-negative.

Agar colonies: Very small, transparent. No gas.

Broth: Turbid.

Litmus milk: Unchanged.

Indole not formed.

Acid from glucose, sucrose and mannitol.

Passes through Chamberland L_2 filters.

Pathogenic for rabbits.

Optimum temperature 37°C.

Anaerobic to microaerophilic.

Source: From respiratory tract in influenza.

Habitat: Mucous membrane of respiratory tract.

Appendix, Family Parvobacteriaceae:* De Bord (Iowa State Coll. Jour. Sci., *16*, 1942, 471) describes a new tribe, *Mimeae*, which may belong in this family. The tribe includes three genera: *Mima* with the species *Mima polymorpha* and the variety *Mima polymorpha* var. *oxidans; Herellea* with the single species *Herellea vaginicola;* and *Colloides* with the single species *Colloides anoxydana.* The organisms are Gram-negative, pleomorphic, motile or non-motile rods, often showing bipolar staining, and were isolated from the normal vagina and from cases of vaginitis and conjunctivitis. Deacon (Jour. Bact., *49*, 1945, 511) classifies nineteen cultures in these genera.

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* Arranged by Dr. A. Parker Hitchens, University of Pennsylvania, Philadelphia, Pa., March, 1946.

FAMILY XII. BACTERIACEAE COHN.*

(Arch. f. path. Anat. u. Physiol., *55*, 1872, 237.)

Rod-shaped cells without endospores. Motile or non-motile. Gram-positive and Gram-negative. Metabolism complex, amino acids being utilized, and generally carbohydrates.

This is a heterogeneous collection of species whose relationships to each other and to other groups are not clear.

Only a single genus is recognized at this time.

Genus I. **Bacterium** *Ehrenberg.*

(IV. Evertebrata, Berlin, 1828, 8.)

The original description of this genus follows:

Bacterium, Novum Genus, Familia Vibrionorum. Character Generis: Corpus polygastricum? anenterum? nudum, oblongum, fusiforme aut filiforme, rectum, monomorphum (contractione nunquam dilatatum), parum flexile (nec aperte undatum), transverse in multas partes sponte dividuum.

This may be translated as follows:

Bacterium, new genus. Family of Vibriona. Character of the genus: Body with many stomachs? without an intestine? naked, oblong, spindle-shaped or filiform, straight, monomorphic (in contraction never dilated), not very pliant (and not definitely wavy), freely separated transversely into many parts.

The type species is *Bacterium triloculare* Ehrenberg.

The original description of this species follows:

B. triloculare nov. spec.; distincte triloculare s. triarticulatum, subfusiformum, hyalinum.

Animalculum 1/300 lineae longum, corpore tereti. Articuli s. septa interna divisionem instantem multiplicem transversam indicare videntur. Mobile sed pigrum animalculum.

In Oasi Jovis Hammonis Siwac observatum, praeterea nullibi.

Bacterii Generis physiologia huiusque obscurra. Cibo colorato Ventriculos replere hae formae respuunt ideoque ad Polygastrica non nisi dubitanter et interim collocantur.

This may be translated as follows:

B. triloculare new. spec. Definitely with three compartments or three jointed, subfusiform, hyaline. Animalcules 1/300 of a line in length, with a smooth body. The joints or internal septa are observed to develop preliminary to multiple transverse splitting. A motile but sluggish animalcule. Observed in the Oasis of Jupiter Ammon of Siwa, nowhere else.

The physiology of the genus *Bacterium* is thus far obscure. These forms refuse to fill their stomachs with colored food and for this reason they are placed with hesitancy and only temporarily in the Polygastrica.

The original descriptions are taken from Buchanan, General Systematic Bacteriology, 1925, 213, and the translations are also furnished by him. Buchanan in his book gives an excellent summary of the nomenclatural status of the term *Bacterium* on pages 213–230.

Since neither the genus nor the type species is characterized in a way to permit definite identification, the term *Bacterium* is used to cover species of non-spore-forming, rod-shaped bacteria whose position in the system of classification is not definitely established (Breed and Conn, Jour. Bact., *31*, 1936, 517).

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* Completely rearranged by Prof. Robert S. Breed and Mrs. Eleanore Heist Clise, New York State Experiment Station, Geneva, New York, May 1946.

Bacterium triloculare Ehrenberg. (Ehrenberg, IV. Evertebrata, Berlin, 1828, 8; *Bacillus ehrenbergii* Trevisan, I generi e le specie delle Batteriacee, 1899, 18; *Bacterium ehrenbergii* De Toni and Trevisan, in Saccardo, Sylloge Fungorum, *8*, 1889, 1022; *Bacterium lineola* Cohn, Beiträge z. Biol. d. Pflanzen, *1*, Heft 2, 1872, 170.) Cohn also regards *Vibrio lineola* Miller, 1786 and *Vibrio lineola* (*Bacillus lineola*, *Bactrium lineola*) of other authors as synonyms of *Bacterium triloculare* as explained by Buchanan (*loc. cit.*, 213 and 521). From Latin *tri*, three and *loculus*, cells or compartments.

Key to the remaining species of genus **Bacterium.**

I. Gram-positive.
  A. Non-motile.
    1. Nitrites produced from nitrates.
      1. *Bacterium erythrogenes.*
      2. *Bacterium subrufum.*
      3. *Bacterium linens.*
      4. *Bacterium mycoides.*
      5. *Bacterium mutabile.*
      6. *Bacterium qualis.*
    2. Nitrites not produced from nitrates.
      a. Grow on ordinary media.
        7. *Bacterium racemosum.*
        8. *Bacterium healii.*
        9. *Bacterium insectiphilium.*
        10. *Bacterium tegumenticola.*
        11. *Bacterium minutaferula.*
        12. *Bacterium fulvum.*
      aa. Grow only on sea water media on fresh isolation.
        13. *Bacterium marinopiscosus.*
        14. *Bacterium sociovivum.*
        15. *Bacterium immotum.*
    3. Action on nitrates unknown.
      16. *Bacterium ammoniagenes.*
      17. *Bacterium minutissimum.*
  B. Motile in young cultures.
    1. Nitrites not produced from nitrates.
      18. *Bacterium incertum.*
      19. *Bacterium imperiale.*
  C. Motile. Proteus-like growth on media.
    1. Nitrites not produced from nitrates.
      20. *Bacterium zopfii.*
      21. *Bacterium zenkeri.*

Appendixes I and II: These list 34 additional species of Gram-positive, motile or non-motile, non-spore-forming, rod-shaped bacteria. See p. 609 and 612.

II. Gram-negative. Digest cellulose. Do not digest agar.
  A. Non-motile. Gelatin liquefied. Chromogenic.
    1. Milk acid.
      22. *Bacterium idoneum.*
      22a. *Bacterium liquatum.*

B. Non-motile. Gelatin liquefied. Non-chromogenic.
 1. Milk acid.
  a. Ammonia produced; indole not formed.
   23. *Bacterium udum.*

C. Non-motile. Gelatin not liquefied. Non-chromogenic.
 1. Milk unchanged.
  a. Ammonia not produced; indole not formed.
   24. *Bacterium lucrosum.*
 2. Milk acid.
  a. Ammonia not produced; indole not formed.
   25. *Bacterium acidulum.*
   26. *Bacterium castigatum.*

D. Motile. Gelatin liquefied. Chromogenic.
 1. Milk acid.
  a. Ammonia produced; indole is formed.
   27. *Bacterium bibulum.*

Appendices I to III: These list additional species of cellulose-digesting, Gram-negative, usually motile, rod-shaped bacteria. See p. 615 and 622. Also similar species that utilize bacterial polysaccharides as a sole source of carbon. See p. 623.

III. Gram-negative. Digest agar.
 A. Non-motile.
  1. Nitrites not produced from nitrates.
   a. Acid from glucose and other sugars.
    28. *Bacterium nenckii.*
   aa. Do not form acid from glucose.
    29. *Bacterium polysiphoniae.*
    30. *Bacterium drobachense.*
  2. Action on nitrates unknown.
   a. Do not form acid from glucose.
    31. *Bacterium delesseriae.*
    32. *Bacterium boreale.*
    33. *Bacterium ceramicola.*
 B. Motile but position of flagella not given. May be either peritrichous or polar.
  1. Nitrites not produced from nitrates.
    34. *Bacterium rhodomelae.*
  2. Action on nitrates unknown.
    35. *Bacterium alginovorum.*
    36. *Bacterium fucicola.*

Appendices I and II: These describe 9 additional species and list others that digest agar. All are Gram-negative, motile or non-motile rod-shaped bacteria. See p. 627.

IV. Gram-negative. Digest chitin.
 A. Motile but position of flagella not given.
  1. Non-chromogenic.
    37. *Bacterium chitinophilum.*
  2. Yellow chromogenesis.
    38. *Bacterium chitinochroma.*

Appendix I: One additional species is described. See p. 632.

V. Gram-negative. Phosphorescent bacteria.
- A. Non-motile coccobacilli from sea water.
  - 1. No liquefaction of gelatin.
    - 39. *Bacterium phosphoreum.*
- B. Motile rods from sea water. Position of flagella not given.
  - 1. No growth in broth, and on coagulated blood serum or potato.
    - 40. *Bacterium phosphorescens indigenus.*
- C. Not stated whether motile or non-motile. From diseased insect larvae.
  - 1. Yellow growth on potato.
    - 41. *Bacterium hemophosphoreum.*

Appendix I: This includes a list of more than 40 additional so-called species of phosphorescent bacteria. See p. 634.

VI. Gram-negative. Facultative autotrophic bacteria which secure energy from the oxidation of hydrogen and utilize carbon from CO_2.
- A. Non-motile.
  - 1. Growth shows a red chromogenesis.
    - 42. *Bacterium erythrogloeum.*
- B. Motile with peritrichous flagella.
  - 1. Yellow chromogenesis.
    - 43. *Bacterium lentulum.*
  - 2. Ivory-colored colonies.
    - 44. *Bacterium leucogloeum.*

VII. Gram-negative. Plant pathogens.
- A. Non-motile.
  - 1. Gelatin not liquefied.
    - 45. *Bacterium stewartii.*
- B. Motile with a polar flagellum.
  - 1. Gelatin not liquefied.
    - a. Colonies mustard yellow on agar.
      - 46. *Bacterium tardicrescens.*
    - b. Colonies honey to Naples yellow on agar.
      - 47. *Bacterium albilineans.*

Appendix I: This includes 19 additional species placed in *Bacterium* or *Bacillus* by their authors. All are reported to cause or to be associated with plant disease. See p. 639.

VIII. Gram-negative. Miscellaneous species.
- A. Produce a pink to red chromogenesis.
  - 1. Motile.
    - a. Gelatin not liquefied.
      - 48. *Bacterium rubefaciens.*
    - aa. Gelatin liquefied.
      - 49. *Bacterium rubidum.*
  - 2. Non-motile.
    - a. Gelatin not liquefied.
      - 50. *Bacterium latericeum.*

B. Do not produce pink or red chromogenesis.
1. Motile.
a. Produce clouding in alginic acid liquid medium.
b. From sea water.
51. *Bacterium alginicum.*
bb. From soil.
52. *Bacterium terrestralginicum.*
aa. Action on alginic acid unknown.
b. Causes a disease of swans.
53. *Bacterium cygni.*
2. Non-motile.
a. Causes red spot disease of carp.
54. *Bacterium cyprinicida.*
aa. Causes liberation of ammonia from a mixture of horse manure and urine.
55. *Bacterium parvulum.*
aaa. Utilizes formates in a liquid medium with the formation of a reddish pellicle.
56. *Bacterium methylicum.*

Appendix I: Miscellaneous described species of non-spore-forming bacteria placed by their authors in the genus *Bacillus*. See p. 643.

Appendix II: Includes anaerobic bacteria that produce methane. See p. 645.

Appendix III: Miscellaneous species of non-spore-forming bacteria listed but not described. See p. 647.

1. **Bacterium erythrogenes** Lehmann and Neumann. (*Bacterium lactis erythrogenes* Grotenfelt, Fortschr. d. Med., *7*, 1889, 41; *Bacillus lactis erythrogenes* Sternberg, Manual of Bact., 1893, 636; Lehmann and Neumann, Bakt. Diag., 1 Aufl., *2*, 1896, 253; *Bacillus erythrogenes* Matzuschita, Bakt. Diagnostik, 1902, 220; *Corynebacterium erythrogenes* Kisskalt and Berend, Cent. f. Bakt., I Abt., Orig., *81*, 1918, 446; *Erythrobacillus erythrogenes* Holland, Jour. Bact., *5*, 1920, 218; *Erythrobacillus (lactis) erythrogenes* Holland, *ibid.*; *Serratia lactica* Bergey et al., Manual, 1st ed., 1923, 93; *Chromobacterium lactis erythrogenes* Topley and Wilson, Princip. Bact. and Immun., *1*, 1931, 402.) From Greek, red-producing.

Micrococcus lactis erythrogenes Conn, Esten and Stocking, Ann. Rept. Storrs (Conn.) Agr. Exp. Sta., *18*, 1906, 117 is stated to be allied to if not identical with the above species.

Rods: 0.3 to 0.5 by 1.0 to 1.4 microns, in broth often up to 4.3 microns long, occurring singly, and having rounded ends. Non-motile. Stain with the usual aniline dyes. Gram-positive (Lehmann and Neumann, *loc. cit.*).

Gelatin colonies: Small, circular, grayish, becoming yellow, sinking into the medium. Crateriform liquefaction. Yellow sediment. Medium becomes rose-colored.

Gelatin stab: Surface growth a whitish, later yellow, circular, thin layer. Weak growth in stab. Slow liquefaction at the surface, the liquid becoming red, with yellow sediment. The solid portion assumes a weak rose color.

Agar stab: Moist, fairly luxuriant, yellow growth, the medium assuming a rose to wine color.

Broth: Turbid, yellow. Pellicle (Fuller and Johnson, Jour. Exp. Med., *4*, 1899, 609).

Litmus milk: Acid. Slow coagulation, having a clear fluid which becomes blood-red in color. Reaction becomes alkaline.

Sterile milk: Casein slowly precipitated, later peptonized. Reaction neu-

tral or alkaline A stratum of blood-red serum is seen above the precipitated casein and above this a yellowish-white layer of cream. An intensive sweet odor that becomes disagreeable.

Potato: Growth rapid, spreading, grayish, later yellow. On incubation a deep golden yellow color develops after 6 to 8 days. A darkening of the medium occurs around the culture, but soon disappears; later the whole potato becomes a weak yellowish-red.

Indole not formed (Fuller and Johnson, *loc. cit.*). Indole formed (Chester, Manual Determ. Bact., 1901, 174).

Blood serum: Liquefied (Fuller and Johnson, *loc. cit.*). Not liquefied (Hefferan, Cent. f. Bakt., II Abt., *11*, 1903, 456).

Nitrites produced from nitrates.

No gas from carbohydrates.

Slight H_2S production (Matzuschita, *loc. cit.*).

Red pigment insoluble in water, alcohol, ether, chloroform, and benzol. Soluble (Hefferan, *loc. cit.*, 529). Yellow pigment insoluble.

Distinctive character: Milk becomes blood-red in 12 to 20 days.

Non-pathogenic for mice (Fuller and Johnson, *loc. cit.*).

Optimum temperature 28° to 35°C.

Aerobic (Fuller and Johnson, *loc. cit.*). Facultative anaerobe (Hefferan, *loc. cit.*, 530).

Source: Isolated from red milk by Hueppe in Wiesbaden in 1886. Isolated from feces of a child by Baginsky (Cent. f. Bakt., *6*, 1889, 137). Isolated from Ohio River water by Fuller and Johnson (*loc. cit.*). Isolated from Mississippi River water by Hefferan (*loc. cit.*). Tataroff isolated a rose fluorescent coccobacterium (*Bacillus rosafluorescens* Kruse, in Flügge, Die Mikroorganismen, 3 Aufl., *2*, 1896, 305; *Bacterium rosa fluorescens* Chester, Ann. Rept. Del. Col. Agr. Exp. Sta., *9*, 1897, 142) which Migula reports as identical, but which Hefferan considers atypical.

Habitat: Probably widely distributed in nature.

2. **Bacterium subrufum** Burri and Staub. (Burri and Staub, Landwirtsch. Jahrb. d. Schweiz, *40*, 1926, 1006; *Serratia subrufa* Bergey et al., Manual, 3rd ed., 1930, 123.) From Latin *sub*, somewhat and *rufus*, red.

This organism is stated to be closely related to or possibly identical with *Bacterium erythrogenes*.

3. **Bacterium linens** Weigmann. (Organismus IX, Wolff, Milchwirt. Zent., *5*, 1909, 145; Weigmann, in Wolff, Cent. f. Bakt., II Abt., *28*, 1910, 422, and in Weigmann, Mykologie der Milch, *62*, 1911, 220.) From Latin, daubing, smearing, or spreading over.

Also see Steinfatt, Milchwirt. Forsch., *9*, 1930, 7; Kelly, Jour. Dairy Sci., *20*, 1937, 239; Albert, Long and Hammer, Iowa Agr. Exp. Sta. Res. Bul. 328, 1944.

Rods: Average 0.62 by 2.5 microns when grown 1 to 2 days on tryptone glucose extract agar. Non-motile (Wolff). Gram-positive (Kelly, *loc. cit.*).

Gelatin colonies: At 18°C punctiform at first; after 12 days about 1 mm in diameter, compact, circular, shiny, brownish-yellow to red-brown. Liquefaction.

Gelatin stab: At 21°C crateriform liquefaction, becoming infundibuliform on extended incubation. Rate of liquefaction varies considerably with different cultures, some completing it in 15 days, others not completing it even on long incubation.

Agar colonies: On tryptone glucose extract agar at 21°C after 1 to 2 days, colonies convex, glistening, entire and cream-colored, becoming brown on extended incubation; diameters 2 to 5 mm. On special cheese agar with incubation in oxygen, luxuriant growth, the color becoming bright orange to reddish-brown in 4 or 5 days.

Agar stab: Heavy surface growth on tryptone glucose extract agar at 21°C with no growth along the line of inoculation.

Agar slant: On tryptone glucose extract agar at 21°C after 2 days growth abundant, glistening, filiform, non-viscid and cream-colored. After extended incubation the color usually is brown. On special cheese agar in an atmosphere of oxygen the growth is bright orange to reddish-brown in 4 or 5 days.

Broth: Turbidity and sediment.

Potato: At 21°C after 5 days, growth is scanty, smooth, glistening, and varies in color from grayish to brownish-orange.

Litmus milk: At 21°C the changes are very slow. After 6 or 7 days the reaction becomes alkaline and a yellow sediment appears. After approximately 10 days some digestion is evident, complete digestion generally requiring several weeks to over a month. A distinct ammoniacal odor, more or less objectionable, produced in old cultures. No coagulation. Ropiness often produced on extended incubation.

Indole not produced.

Nitrites produced from nitrates.

Methyl red and Voges Proskauer reactions negative.

Hydrogen sulfide produced in broth and on agar by some cultures but not by others.

Natural fats not hydrolyzed.

No acid or gas from arabinose, dextrin, glucose, dulcitol, galactose, inulin, lactose, fructose, maltose, mannitol, raffinose, rhamnose, salicin, sorbitol, sucrose or xylose.

Ethyl, propyl, butyl and amyl alcohols oxidized largely to corresponding acids; hexyl and heptyl alcohols attacked much less actively.

Catalase rapidly produced in or on various media.

Aerobic.

Growth temperatures: Growth at 8° and 37°C but not at 45°C, with the optimum at about 21°C.

Heat resistance low, cultures being killed at 62.8°C in a few minutes.

Growth in the pH range 6.0 to 9.8; no growth at pH 5.0 or below.

Salt tolerant, cultures growing readily in a concentration of 15 per cent salt in broth or skim milk, with certain cultures apparently capable of growing somewhat in much higher concentrations.

Closely related to or identical with *Bacterium erythrogenes* Lehmann and Neumann.

Source: Originally isolated by Wolff from the surface flora of various soft cheeses.

Habitat: Widely distributed in and especially on the surface of dairy products including blue, brick, camembert, limburger, oka and cheddar cheeses, butter, milk and cream. Also found in various feeds including grains, silage, green plants, hay and straw, and in water, soil, manure, and air.

4. **Bacterium mycoides** (Grotenfelt) Migula. (*Bacterium mycoides roseum* Grotenfelt, Fortschr. d. Med., 7, 1889, 46; *Bacillus mycoides roseus* Sternberg, Manual of Bact., 1893, 640; Migula, Syst. d. Bakt., *2*, 1900, 482; *Bacillus mycoides-roseus* Holland, Jour. Bact., *5*, 1920, 219; *Erythrobacillus mycoides-roseus* Holland, *ibid.*; *Serratia rosea* Bergey et al., Manual, 1st ed., 1923, 96; *Chromobacterium mycoides roseum* Topley and Wilson, Princip. of Bact. and Immun., *1*, 1931, 402.) From Greek *mykes*, fungus and *eidos*, form.

Rods: Non-motile. Gram-positive.

Gelatin colonies: Red, felt-like. Liquefaction.

Gelatin stab: Rapid liquefaction. Red pellicle. Red sediment.

Colonies composed of interlacing filaments (Crookshank, Textb. of Bact. and Inf. Dis., 1900, 524).

Agar stab: Red color produced if grown in dark; a white color in presence of light.

Optimum temperature: Room temperature.

Pigment soluble in water.

Distinctive characters: Morphologically like the anthrax bacillus. Appearance in gelatin. Production of a brilliant rose color when grown in the dark; colonies grown in the light are white, but they assume the red color if developed further in the dark.

Source: Isolated from Wiesbaden soil by Scholl.

Habitat: Unknown.

NOTE: It has been claimed that this or a similar organism forms spores (Matzuschita, Bact. Diag., 1902, 168; Perlberger, Cent. f. Bakt., II Abt., *62*, 1924, 8). However cultures of Scholl's organism received from the Kràl collection by Hefferan (Cent. f. Bakt., II Abt., *11*, 1903, 458) and by Breed in 1926 (personal communication) did not form spores. These cultures produced nitrites from nitrates and failed to liquefy gelatin.

5. **Bacterium mutabile** Steinhaus. (Jour. Bact., *42*, 1941, 775.) From Latin *mutabilis*, changeable.

Short rods: On agar, 0.7 to 0.9 by 1.0 to 2.0 microns. In fluid media, such as tryptophane broth, pleomorphic, bizarre forms frequently appearing slightly branched. Non-motile. Gram-positive.

Gelatin stab: Very slow liquefaction.

Agar colonies: Cream to yellow, circular, smooth, glistening, opaque.

Broth: Moderate turbidity, slight sediment.

Litmus milk: Alkaline, soft curd, slow peptonization.

Indole not produced.

Hydrogen sulfide not produced.

Nitrites produced from nitrates.

Starch not hydrolyzed.

Glucose, lactose, sucrose and maltose not fermented.

Aerobic.

Source: From the alimentary tract of the lyreman cicada, *Tibicen linnei* Smith and Grossbeck.

Habitat: Unknown.

6. **Bacterium qualis** Steinhaus. (Jour. Bact., *42*, 1941, 774.) From Latin *qualis*, of what kind.

Short rods: Very short on solid media, frequently ellipsoidal in shape. In fluid media: 0.5 to 0.7 by 1.4 to 2.2 microns, occurring singly. Non-motile. Gram-positive.

Gelatin stab: Liquefaction.

Agar colonies: Small (1 mm), white, glistening, transparent, circular, entire.

Agar slant: Filiform, smooth, glistening.

Broth: Almost clear; slight turbidity in serum and glucose broth.

Litmus milk: No change.

Indole not produced.

Hydrogen sulfide not produced.

Slight production of nitrites from nitrates.

Starch not hydrolyzed.

Acid from glucose, sucrose and maltose. Lactose not fermented.

Source: From the alimentary tract of the tarnished plant bug, *Lygus pratensis* L.

Habitat: Unknown.

7. **Bacterium racemosum** Zettnow. (Zettnow, Cent. f. Bakt., I Abt., Orig., 77, 1915, 209; *Zettnowia racemosa* Enderlein, Bakt. Cyclogenie, Berlin, 1925, 259; *Flavobacterium racemosum* Bergey et al., Manual, 1st ed., 1923, 115.) From Latin *racemosus*, branching.

Filaments: 0.5 to 0.8 by 10 to 12 microns. Branching forms found. Non-motile. Gram-positive.

Gelatin colonies: White, circular, soft, granular, brownish, entire.

Gelatin stab: White surface growth. Liquefaction napiform.

Agar slant: Light yellow, limited growth.

Broth: Turbid.

Litmus milk: Coagulated, becoming alkaline.

Potato: Dirty-yellowish, limited streak.

Indole not formed.

Nitrites not produced from nitrates.

Aerobic, facultative.

Optimum temperature 20°C.

This species is selected as the type species for the genus *Zettnowia* Enderlein (*loc. cit.*).

Source: Contamination on agar plate.

Habitat: Unknown.

8. **Bacterium healii** Buchanan and Hammer. (Buchanan and Hammer, Iowa Agr. Exp. Sta. Research Bull. 22, 1915, 249; *Escherichia healii* Bergey et al., Manual, 1st ed., 1923, 200; *Achromobacter healii* Bergey et al., Manual, 2nd ed., 1925, 157.)

Rods: 0.5 to 0.7 by 2.2 to 12.9 microns, occurring singly and in short chains. Non-motile. Gram-positive.

Gelatin stab: Stratiform liquefaction. Villous growth in stab.

Agar colonies: Large, white, rhizoid.

Agar slant: White, hard growth, with no tendency to stringiness.

Broth: Gray pellicle and sediment.

Litmus milk: Slightly acid, becoming slimy, coagulated, peptonized.

Potato: Heavy, white, glistening growth.

Indole not formed.

Nitrites not produced from nitrates.

Acid without gas from glucose, fructose, maltose, sucrose, salicin and starch. No acid from mannitol, lactose, raffinose or inulin.

Aerobic, facultative.

Optimum temperature 22°C.

Source: Slimy milk.

Habitat: Unknown.

9. **Bacterium insectiphilium** Steinhaus. (Jour. Bact., *42*, 1941, 777.) From M. L. *insect*, insect and Greek *philos*, loving.

Rods: 0.8 to 1.2 by 1.0 to 2.8 microns, occurring singly. At times appearing almost as cocci or coccobacilli. Non-motile. Gram-positive.

Gelatin stab: Liquefaction.

Agar colonies: Light greenish-yellow, circular, entire, raised, glistening, smooth, opaque.

Agar slant: Filiform, raised, smooth, glistening, opaque growth.

Broth: Moderate turbidity, slight viscid sediment.

Litmus milk: Alkaline, peptonization, and slow reduction.

Potato: Greenish-yellow, thick, moist growth.

Indole not produced.

Nitrites not produced from nitrates.

Hydrogen sulfide not produced.

Starch slightly hydrolyzed.

No action on the following carbohydrates: Glucose, lactose, sucrose, maltose, fructose, mannitol, galactose, arabinose, xylose, dextrin, salicin, rhamnose, raffinose, trehalose, sorbitol, inulin, dulcitol, glycerol, adonitol, mannose.

Aerobic.

Source: From the body wall of the bagworm, *Thyridopteryx ephemeraeformis* Haw.

Habitat: Unknown.

10. **Bacterium tegumenticola** Steinhaus. (Jour. Bact., *42*, 1941, 775.) From Latin *tegumentum*, cover, skin and *cola*, dweller.

Small rods: 0.5 to 0.8 by 1.0 to 1.5 microns. Have a tendency to be ellipsoidal on solid media. Non-motile. Gram-positive.

Gelatin stab: Generally no liquefaction. Variable.

Agar colonies: Tiny (1 mm), white, convex, glistening, circular, entire.

Agar slant: Filiform, glistening, grayish-white growth.

Broth: Slight turbidity; sediment.

Litmus milk: No change.

Indole not produced.

Hydrogen sulfide not produced.

Nitrites not produced from nitrates.

Starch not hydrolyzed.

Acid slowly produced from glucose

and maltose. Acid from sucrose. Lactose not fermented.

Source: From the integument of the bed-bug, *Cimex lectularius* L.

Habitat: Unknown.

11. **Bacterium minutaferula** Steinhaus. (Jour. Bact., 42, 1941, 778.) From Latin, small rod.

Very small rods: 0.4 to 0.9 by 0.7 to 1.0 micron, occurring singly. Non-motile. Gram-positive.

Gelatin stab: No liquefaction.

Agar colonies: Colorless to faint gray, circular, smooth, entire, glistening.

Agar slant: Very thin, transparent, glistening growth.

Broth: Slight turbidity and sediment.

Litmus milk: No change at first; slightly acid after one week.

Indole not produced.

Hydrogen sulfide not produced.

Nitrites not produced from nitrates.

Starch not hydrolyzed.

Acid from glucose after 4 days. Slight acid from sucrose. Lactose and maltose not fermented.

Aerobic.

Source: From triturated specimen of the mud-dauber wasp, *Sceliphron cementarium* Dru.

Habitat: Unknown.

12. **Bacterium fulvum** (Zimmermann) Chester. (*Bacillus fulvus* Zimmermann, Bakt. unserer Trink- u. Nutzwässer, Chemnitz, *1*, 1890, 44; Chester, Ann. Rept. Del. Col. Agr. Exp. Sta., *9*, 1897, 107; *Flavobacterium fulvum* Bergey et al., Manual, 1st ed., 1923, 115.) From Latin *fulvus*, dull yellow.

Rods: 0.8 by 0.9 to 1.3 microns, occurring singly, in pairs and in chains. Non-motile. Gram-positive.

Gelatin colonies: Circular, convex, reddish-yellow.

Gelatin stab: Convex, reddish-yellow surface growth. Good growth in stab. Slow liquefaction.

Agar slant: Orange-red, glistening streak.

Broth: Turbid with yellow sediment.

Litmus lactose broth: Acid, or acid then alkaline (Dyar, Ann. N. Y. Acad. Sci., *8*, 1895, 368).

Potato: Slowly spreading, yellowish, glistening growth.

Indole formed (Dyar, *loc. cit.*).

Nitrites not produced from nitrates (Bergey).

Aerobic, facultative.

Optimum temperature 30°C.

Source: From Chemnitz and Döbeln tap water (Zimmermann). From dust and water (Dyar).

Habitat: Water.

13. **Bacterium marinopiscosus** ZoBell and Upham. (Bull. Scripps Inst. Oceanography, La Jolla, *5*, 1944, 258.) From Latin *marinus*, pertaining to the sea, and *piscosus*, fish.

Rods: 1.2 to 1.6 by 2.0 to 4.7 microns, with rounded ends, show granular staining, occurring singly, in pairs and long chains. Non-motile. Gram-positive, but many cells tend to decolorize leaving Gram-positive granules.

All differential media except the fresh-water broth, litmus milk, and potato were prepared with sea water.

Gelatin colonies: Gray, circular, convex, 1 mm. No pigment.

Gelatin stab: Liquefaction napiform, becoming crateriform to stratiform with age. Complete in 50 days.

Agar colonies: 2 to 4 mm, circular, convex, entire, smooth, irregular edge.

Agar slant: Luxuriant, beaded, glistening, butyrous growth with no pigment.

Sea-water broth: No turbidity, abundant flocculent sediment, slight surface ring.

Fresh-water broth: Good growth.

Litmus milk: Decolorized, neutral, top peptonized.

Potato: Heavy, white, raised, mucoid, dull growth. Potato darkened.

Indole not formed.

Nitrites not produced from nitrates.

Acid but no gas from glucose and man-

nitol. No acid from maltose, lactose, sucrose, glycerol, xylose or salicin.

Starch is hydrolyzed.

Hydrogen sulfide not formed.

Ammonia produced from peptone but not from urea.

Casein is digested.

Fats are not hydrolyzed.

Aerobic, facultative.

Optimum temperature 20° to 25°C.

Source: Found on the skin of marine fish.

Habitat: Not known from other sources.

14. **Bacterium sociovivum** ZoBell and Upham. (Bull. Scripps Inst. Oceanography, La Jolla, *5*, 1944, 269.) From Latin *socius*, associate and *vivum*, to live.

Rods: 0.5 to 0.8 by 3.0 to 4.0 microns, with rounded ends, occurring singly, in pairs, and chains. Non-motile. Gram-positive but tends to destain, leaving Gram-positive cell wall and granules.

All differential media except the fresh-water broth, litmus milk and potato were prepared with sea water.

Gelatin colonies: Irregular, sunken, filamentous margin, grayish-white.

Gelatin stab: Crateriform liquefaction becoming stratiform.

Agar colonies: 2 to 4 mm, circular, convex, smooth, entire, darker center.

Agar slant: Luxuriant, beaded, glistening, butyrous growth with no pigment.

Sea-water broth: No pellicle, no turbidity, heavy flocculent sediment.

Fresh-water broth: Fair growth.

Litmus milk: Decolorized, neutral, completely peptonized in 20 days.

Potato: Abundant, dull, light cream-colored growth. Potato darkened.

Indole not formed.

Nitrites not produced from nitrates.

Acid but no gas from glucose, maltose, and mannitol. No acid from glycerol, lactose, sucrose, or salicin.

Starch is hydrolyzed.

Hydrogen sulfide not formed.

Ammonia produced from peptone but not from urea.

Casein is digested.

Fats not hydrolyzed.

Aerobic, facultative.

Optimum temperature 20° to 25°C.

Source: Found associated with sedentary organisms in the sea.

Habitat: Commonly found on submerged surfaces and on sessile diatoms in sea water.

15. **Bacterium immotum** ZoBell and Upham. (Bull. Scripps Inst. Oceanography, *5*, 1944, 271.) From Latin, meaning immobile or stationary.

Rods: 0.8 by 3.1 to 8.6 microns, with rounded ends, occurring singly, in pairs, and long chains. Non-motile. Gram-positive but tend to destain leaving Gram-positive outline and granules.

All differential media except the fresh-water broth, litmus milk, and potato were prepared with sea water.

Gelatin colonies: Small, circular, raised, gray, slowly digest gelatin.

Gelatin stab: Crateriform liquefaction becoming infundibuliform. Beaded growth along line of stab. No pigment.

Agar colonies: 1 to 2 mm, circular, convex, smooth, lobate margin, darker centers.

Agar slant: Luxuriant, glistening, echinulate, mucoid growth with no pigment.

Sea-water broth: No pellicle, moderate turbidity, abundant, flocculent sediment.

Fresh-water broth: Scanty growth.

Litmus milk: Decolorized, neutral, partly peptonized in 20 days.

Potato: Luxuriant, mucoid, creamy growth which darkens potato.

Indole not formed.

Nitrites not produced from nitrates.

Acid but no gas from glucose, maltose, xylose, and mannitol. No acid from glycerol, lactose, sucrose, or salicin.

Starch is hydrolyzed.

Hydrogen sulfide not formed.

Ammonia produced from peptone but not from urea.

Casein is digested.

Fats not hydrolyzed.

Aerobic, facultative.

Optimum temperature 20° to 25°C.

Source: Found associated with marine sedentary organisms.

Habitat: Not known from other sources.

16. **Bacterium ammoniagenes** Cooke and Keith. (Cooke and Keith, Jour. Bact., *13*, 1927, 315; *Alcaligenes ammoniagenes* Bergey et al., Manual, 3rd ed., 1930, 367.) From M. L. *ammonia* and Latin *genero*, develop.

Rods with rounded ends, 0.8 by 1.4 to 1.7 microns, occurring singly. Non-motile. Gram-positive.

Gelatin stab: No liquefaction.

Agar colonies: Circular, flat, smooth, entire, gray.

Agar slant: Growth moderate, smooth, flat, opaque, glistening, butyrous, amorphous.

Broth: Moderate turbidity, with flocculent sediment.

Litmus milk: Slightly alkaline.

Indole not formed.

No action on carbohydrates.

Blood serum not liquefied.

Urea is fermented forming ammonia.

Aerobic, facultative.

Optimum temperature 30°C.

Source: From feces of infants.

Habitat: Presumably widely distributed in putrefying materials.

17. **Bacterium minutissimum** Migula. (*Bacillus pyogenes minutissimus* Kruse, in Flügge, Die Mikroorganismen, 3 Aufl., *2*, 1896, 447; *Bacterium pyogenes minutissimus* Chester, Ann. Rept. Del. Col. Agr. Exp. Sta., *9*, 1897, 89; Migula, Syst. d. Bakt., *2*, 1900, 418; *Eberthella minutissima* Bergey et al., Manual, 1st ed., 1923, 228; *Shigella minutissima* Bergey et al., Manual, 3rd ed., 1930, 359.) From Latin, smallest.

Description from Kruse (*loc. cit.*). Description not different from that of *Bacillus tenuis sputigenes* Pansini, according to Chester (Ann. Rept. Del. Col. Agr. Exp. Sta., *9*, 1897, 89).

Rods: 0.5 by 1.0 micron, occurring singly and in pairs. Non-motile. Gram-positive.

Gelatin stab: No liquefaction. Yellowish growth spreading slightly on surface.

Growth on agar and blood serum is not characteristic.

Acid but no gas from glucose and lactose.

No characteristic odor.

Not pathogenic for mice and rabbits.

Aerobic, facultative.

Optimum temperature 37°C.

Source: Isolated from a facial abscess.

Habitat: Not known from other sources.

18. **Bacterium incertum** Steinhaus. (Jour. Bact., *42*, 1941, 776.) From Latin *incertus*, uncertain.

Short rods: 0.5 to 0.8 by 1.0 to 1.5 microns, occurring singly and occasionally in pairs. Young cultures motile, after 48 hours generally non-motile. Gram-positive; after 48 hours many cells become Gram-negative.

Gelatin stab: No liquefaction.

Agar colonies: Tiny, grayish-white, smooth, almost transparent. Does not grow well on nutrient agar.

North's gelatin chocolate agar slant: Filiform, thin, transparent growth. Brown color of chocolate medium changes to yellowish-green.

Blood agar: Alpha hemolysis at first; after three days beta hemolysis.

Broth: Almost clear; very slight growth.

Litmus milk: No change.

Indole not produced.

Hydrogen sulfide not produced.

Nitrites not produced from nitrates.

Starch not hydrolyzed.

Acid but no gas from glucose, sucrose,

fructose, mannose, and maltose. No fermentation of lactose, rhamnose, galactose, mannitol, dulcitol, inositol, or sorbitol.

Voges-Proskauer test: Negative.

Microaerophilic.

Source: From the ovaries of the lyreman cicada, *Tibicen linnei* Smith and Grossbeck.

Habitat: Unknown.

19. **Bacterium imperiale** Steinhaus. (Jour. Bact., *42*, 1941, 777.) From Latin *imperialis*, referring to the imperial moth.

Small rods: 0.5 to 0.8 by 1.0 to 1.7 microns, occurring singly and in pairs. A few cells motile in young cultures. Gram-positive.

Gelatin stab: No liquefaction.

Agar colonies: Circular, entire, almost translucent, pinkish-orange to yellow pigment.

Agar slant: Filiform, glistening, opaque growth.

Broth: Slight to moderate turbidity; slight sediment.

Litmus milk: No change at first, later slightly acid.

Potato: Heavy, glistening, moist growth; reddish to yellowish-orange.

Indole not produced.

Hydrogen sulfide not produced.

Nitrites not produced from nitrates.

Starch not hydrolyzed.

Acid but no gas from glucose, sucrose, maltose, fructose, mannitol, galactose, arabinose, xylose, salicin, raffinose, trehalose, sorbitol, mannose, adonitol, esculin, and slight acid from lactose and dextrin. Inulin, dulcitol, glycerol, rhamnose, adonitol, and inositol not fermented.

Aerobic.

Source: From the alimentary tract of the imperial moth, *Eacles imperialis* Dru.

Habitat: Unknown.

20. **Bacterium zopfii** Kurth. (Kurth, Bericht. d. deutsch. Botan. Gesellschaft, *1*, 1883, 97; *Kurthia zopfii* Trevisan, Atti della Accad. Fisio-Medico-Statistica in Milano, Ser. 4, *3*, 1885, 92; *Helikobacterium zopfii* Escherich, Münch. med. Wchnschr., *33*, 1886, 2, quoted from Enlows, U. S. Hygienic Lab. Bull. 121, 1920, 47; *Bacterium (Proteus) zopfii* Chester, Ann. Rept. Del. Col. Agr. Exp. Sta., *9*, 1897, 103; *Bacillus zopfii* Migula, Syst. d. Bakt., *2*, 1900, 815; *Zopfius zopfii* Wenner and Rettger, Jour. Bact., *4*, 1919, 334.) Named for W. Zopf, German botanist.

This is the type species of the genus *Kurthia* Trevisan. (Trevisan, *loc. cit.*; *Zopfius* Wenner and Rettger, Jour. Bact., *4*, 1919, 334.)

Rods: 0.8 by 3.5 microns, with rounded ends, occurring in long curved chains. Motile with peritrichous flagella. Gram-positive.

Gelatin colonies: Radiate, filamentous, gray.

Gelatin stab: Arborescent growth in stab. No liquefaction.

Agar colonies: Fimbriate.

Agar slant: Spreading, gray, fimbriate growth.

Broth: Slow, moderate growth.

Litmus milk: No change.

Potato: Moderate, gray growth; medium becoming dark.

No H_2S produced.

Indole not formed.

Nitrites not produced from nitrates.

Aerobic, facultative.

Optimum temperature 25° to 30°C.

Habitat: Decomposing materials.

21. **Bacterium zenkeri** (Hauser) Chester. (*Proteus zenkeri* Hauser, Ueber Faulnissbakterien, 1885; *Bacillus zenkeri* Trevisan, I generi e le specie delle Batteriacee, 1889, 17; Chester, Ann. Rept. Del. Col. Agr. Exp. Sta., *9*, 1897, 103; *Zopfius zenkeri* Wenner and Rettger, Jour. Bact., *4*, 1919, 334; *Bacillus proteus-zenkeri* Holland, Jour. Bact., *5*, 1920, 220; *Kurthia zenkeri* Bergey et al., Manual, 2nd ed., 1925, 215.) Named for K. Zenker, German pathologist.

Rods: 0.65 by 1.6 to 2.3 microns, occurring in pairs and in chains. Motile with peritrichous flagella. Gram-positive.

Gelatin colonies: Feathery, with filaments extending in all directions.

Gelatin stab: Surface growth like colonies. No arborescent growth in stab. No liquefaction.

Agar colonies: Thin, filamentous, spreading, grayish.

Agar slant: Thin, bluish-gray, filamentous growth.

Broth: Slightly turbid, with gray sediment.

Litmus milk: No change.

Potato: Barely visible, yellowish-gray, glistening growth.

Indole not formed.

Nitrites not produced from nitrates.

No H_2S formed.

Aerobic, facultative.

Optimum temperature 30°C.

Habitat: Decomposing materials.

NOTE: Wenner and Rettger, *loc. cit.*, consider the last two species to be identical.

Appendix I: The following Gram-positive, motile species may belong with the above group. All have been placed at one time or another in the genus *Achromobacter* or in the genus *Flavobacterium*.

1. **Achromobacter lipolyticum** (Huss) Bergey et al. (*Bactridium lipolyticum* Huss, Cent. f. Bakt., II Abt., *20*, 1908, 474; Bergey et al., Manual, 2nd ed., 1925, 158.) From Greek, fat-dissolving.

Small, oval rods: 0.3 to 0.5 by 0.7 to 1.4 microns. Motile, possessing peritrichous flagella. Gram-positive.

Gelatin colonies: Circular, grayish to transparent with irregular margin.

Gelatin stab: Infundibuliform liquefaction.

Agar colonies: Growth circular, gray, smooth, glistening, with entire margin.

Broth: Turbid with granular sediment.

Litmus milk: Coagulated, peptonized, becoming alkaline.

Potato: Moist, glistening, grayish growth.

Indole is formed.

Acid from glucose, sucrose, raffinose, xylose, mannitol and glycerol.

Fats are split in milk, giving rise to a rancid odor and a bitter taste.

Aerobic, facultative.

Optimum temperature 35°C.

Source: From the udder of a cow giving abnormal milk.

Habitat: Milk.

2. **Achromobacter stearophilum** (Weinzirl) Bergey et al. (*Bacillus stearophilus* Weinzirl, Jour. Med. Res., *39*, 1919, 404; Bergey et al., Manual, 1st ed., 1923, 145.)

Rods: 0.8 by 5.0 microns, occurring singly. Motile. Gram-positive.

Gelatin colonies: Scanty development.

Pumpkin gelatin stab: Filiform growth in stab. No liquefaction.

Pumpkin agar colonies: Small, smooth, convex, gray, entire.

Pumpkin juice: Slightly turbid.

Pumpkin milk: Acid, coagulated.

Potato: Slight, smooth, gray, glistening, filiform growth.

Indole not formed.

Nitrites not produced from nitrates.

No acid from carbohydrate media.

Starch from pumpkin hydrolyzed.

Aerobic, facultative.

Optimum temperature 20°C.

Source: Canned pumpkin.

Habitat: Unknown.

3. **Achromobacter sulfureum** Bergey et al. (Bakt. 4, Rubentschick, Cent. f. Bakt., II Abt., *72*, 1927, 123; Bergey et al., Manual, 3rd ed., 1930, 220.)

Rods: 0.7 to 0.8 by 1.7 to 2.2 microns, occurring singly and in pairs. Motile. Gram-positive.

Gelatin stab: Saccate liquefaction.

Agar colonies: Circular, grayish-white, flat, homogeneous.

Agar slant: Filiform, grayish-white, smooth, homogeneous growth. Metallic luster.

Broth: Turbid.

Litmus milk: Peptonized.

Potato: Yellowish-brown layer.

Indole not formed.

Nitrites produced from nitrates with gas formation.

Hydrogen sulfide formed.

Ammonia formed.

Urea is attacked.

Methylene blue reduced.

Aerobic, facultative.

Optimum temperature 30° to 33°C. Can grow at 0°C.

Source: Sewage filter beds.

Habitat: Putrefying materials.

NOTE: See *Pseudomonas urease* Bergey et al. for another motile, Gram-positive organism described by Rubentschick (Bakt. 3) from the same source.

4. **Achromobacter aerophilum** (Rubentschick) Bergey et al. (*Urobacterium aerophilum* Rubentschick, Cent. f. Bakt., II Abt., *64*, 1925, 168; Bergey et al., Manual, 3rd ed., 1930, 224.)

Rods: 0.75 to 0.85 by 2.0 to 4.5 microns, occurring singly, in pairs, and in chains. Motile. Gram-positive.

Urea gelatin colonies: Small, circular, dirty-gray, entire.

Urea gelatin stab: No liquefaction.

Urea agar colonies: Circular, grayish, smooth.

Urea agar slant: Dirty-gray, glistening to dry growth.

Urea broth: Turbid.

Urea milk: Unchanged.

Urea potato: Slight, grayish-white streak.

Indole not formed.

Nitrites produced from nitrates.

H_2S not formed.

Ammonia not formed.

Aerobic, facultative.

Source: Sewage slime.

Habitat: Putrefying materials.

5. **Achromobacter citrophilum** (Rubentschick) Bergey et al. (*Urobacterium citrophilum* Rubentschick, Cent. f. Bakt., II Abt., *64*, 1925, 168; *66*, 1926, 161; *67*, 1926, 167; *68*, 1926, 327; Bergey et al., Manual, 3rd ed., 1930, 224.)

Rods: 0.75 to 0.85 by 2.5 to 6.0 microns, occurring singly and in pairs. Motile. Gram-positive.

Urea gelatin colonies: Small, grayish-white, smooth, undulate.

Urea gelatin stab: No liquefaction.

Urea agar slant: Filiform, grayish-white, thin, dry growth.

Urea broth: Turbid.

Urea milk: Unchanged.

Urea potato: Dirty-gray, thin streak.

Indole not formed.

Nitrites produced from nitrates.

Hydrogen sulfide not formed.

Ammonia not formed.

Can derive oxygen from sodium citrate.

Aerobic, facultative.

Optimum temperature 30°C.

Source: Sewage slime.

Habitat: Putrefying materials.

6. **Flavobacterium sulfureum** Bergey et al. (*Bacterium punctans sulfureum* Zettnow, Cent. f. Bakt., I Abt., Orig., *77*, 1916, 222; Bergey et al., Manual, 1st ed., 1923, 103.)

Rods: 0.5 to 0.7 by 0.7 to 1.5 microns. Motile, possessing peritrichous flagella. Gram-positive.

Gelatin colonies: Very small, barely visible, becoming brownish-yellow, granular.

Gelatin stab: Spreading growth on the surface only. Later crateriform liquefaction.

Agar slant: Sulfur-yellow growth.

Broth: Turbid.

Litmus milk: Alkaline, peptonized, yellow.

Potato: Sulfur-yellow streak.

Indole not formed.

Nitrites not produced from nitrates.

Blood serum: Sulfur-yellow growth. Partial liquefaction.

No acid from glucose.

Aerobic, facultative.

Optimum temperature 25°C.

Source: Air.
Habitat: Unknown.

7. **Flavobacterium acetylicum** Levine and Soppeland. (Bull. 77, Engineering Exp. Sta., Iowa State Agricultural College, 1926, 46.) From the chemical term acetyl.

Rods: 0.9 by 1.1 microns, with rounded ends, occurring singly and in pairs. Motile. Gram-positive.

Gelatin stab: Stratiform liquefaction.

Agar colonies: Irregular in form, yellow, smooth, flat, amorphous, entire.

Agar slant: Abundant, echinulate growth, flat, peach yellow, smooth and butyrous.

Broth: Ring growth on surface. Turbid with scant sediment.

Litmus milk: Slight acidity, with granular curd. Peptonization. Litmus reduced.

Potato: Moderate, orange growth.

Indole not formed.

Nitrites not produced from nitrates.

Starch hydrolyzed.

Blood serum liquefied.

Acid from glucose with formation of acetylmethylcarbinol.

Aerobic, facultative.

Optimum temperature 22°C.

Source: From skimmed milk.

Habitat: Unknown.

8. **Flavobacterium fuscum** (Zimmermann) Bergey et al. (*Bacillus fuscus* Zimmermann, Bakt. unserer Trink- und Nutzwässer, Chemnitz, *1*, 1890, 70; not *Bacillus fuscus* Flügge, Die Mikroorganismen, 2 Aufl., 1886, 290; *Bacterium fuscus* Chester, Ann. Rept. Del. Col. Agr. Exp. Sta., *9*, 1897, 111; Bergey et al., Manual, 1st ed., 1923, 113; *Chromobacterium fuscum* Topley and Wilson, Princ. Bact. and Immun., *1*, 1931, 405.) From Latin *fuscus*, tawny.

Rods: 0.6 by 1.5 microns, occurring singly. Non-motile. Gram-positive.

Gelatin colonies: Small, with brownish center and yellowish border.

Gelatin stab: Gray, filiform growth in stab. Slow crateriform liquefaction.

Agar colonies: Circular, pale yellow, smooth, slightly convex, entire.

Agar slant: Growth greenish-yellow, plumose, smooth, raised, undulate.

Broth: Turbid, with pellicle and sediment.

Litmus milk: Slightly acid, becoming alkaline, with yellow ring.

Potato: Thick, moist, chrome-yellow streak.

Indole not formed.

Nitrites produced from nitrates.

Aerobic, facultative.

Optimum temperature 30°C.

Source: From Zwönitz River water.

Habitat: Water.

8a. *Bacterium fuscum liquefaciens* (Dyar) Chester. (*Bacillus fuscus liquefaciens* Dyar, Ann. N. Y. Acad. Sci., *8*, 1895, 375; Chester, Ann. Rept. Del. Col. Agr. Exp. Sta., *9*, 1897, 108.) Received from the Kràl collection labeled *Bacillus fuscus*; also from air. Differs from the above only in liquefying gelatin more slowly and completely.

9. **Flavobacterium maris** Harrison. (Canadian Jour. Research, *1*, 1929, 232.) From Latin *mare*, sea.

Rods: 0.7 to 0.8 by 1.0 to 1.2 microns, occurring singly and in pairs. At 37°C coccoid. Non-motile. Encapsulated. Gram-positive.

Gelatin colonies: Punctiform, red-orange, granular, entire.

Gelatin stab: Red-orange surface growth, filiform growth in stab. No liquefaction.

Agar colonies: Circular, orange-yellow, smooth, glistening, convex.

Agar slant: Growth moderate, orange-yellow, becoming cadmium-orange to red-orange, spreading, glistening.

Broth: Clear with orange pellicle and sediment.

Litmus milk: At first faintly alkaline, becoming faintly acid with orange sediment.

Potato: Scant growth.

Indole not formed.

Nitrites produced from nitrates.

Traces of ammonia formed.

Faint acidity from glucose. No action on lactose or sucrose.

Loeffler's blood serum not liquefied.

No H_2S formed.

Aerobic, facultative.

Optimum temperature 20° to 25°C.

Source: Isolated from the skin of fishes. Steinhaus (Jour. Bact., *42*, 1941, 771) found a similar organism in the intestine of a caterpillar.

Habitat: Unknown.

Appendix II: Among the following species reported as Gram-positive are many that appear to be similar to the species listed above, while others may belong to the so-called parasitic lactobacilli of the intestine or even to *Corynebacterium*. The majority have been placed by their authors in genera other than *Bacterium*.

Bacillus achrous Migula. (No. 6, Lembke, Arch. f. Hyg., *26*, 1896, 301; Migula, Syst. d. Bakt., *2*, 1900, 676.) From feces. Motile.

Bacillus asteriformis Migula. (Microbe astériforme, de Klecki, Ann. Inst. Past., *9*, 1895, 735; Migula, Syst. d. Bakt., *2*, 1900, 816.) From feces. Motile. Colonies resemble those of *Bacillus mycoides* but no spores are mentioned.

Bacillus casei limburgensis Orla-Jensen. (Orla-Jensen, Cent. f. Bakt., II Abt., *13*, 1904, 702; *Bacterium casei limburgensis* Yale, N. Y. S. Agr. Exp. Sta., Tech. Bul. 268, 1943, 5.) From limburger cheese. Presumably the same as *Bacterium linens* Weigmann.

Bacillus choukevitchi Herter. (Microbe VIII, Choukévitch, Ann. Inst. Past., *25*, 1911, 265; Herter, Just's Botan. Jahresber., *39*, 2 Abt., Heft 4, 1915, 748.) From the large intestine of a horse.

Bacillus colorabilis Migula. (Bacillus der Gallenblase, Naunyn, Deutsche med. Wochnschr., 1891, 193; *Bacillus cuniculicida havaniensis* Sternberg, Man. of Bact., 1893, 450; *Bacillus coli colorabilis* Kruse, in Flügge, Die Mikroorganismen, 3 Aufl., *2*, 1896, 434; *Bacterium coli colorabilis* Chester, Ann. Rept. Del. Col. Agr. Exp. Sta., *9*, 1897, 87; *Bacterium cuniculicida havaniensis* Chester, *idem*; Migula, Syst. d. Bakt., *2*, 1900, 736.) From a diseased gall-bladder (Naunyn) and from the intestines and liver of yellow-fever cadavers (Sternberg).

Bacillus cupularis Migula. (No. 12, Lembke, Arch. f. Hyg., *26*, 1896, 307; Migula, Syst. d. Bakt., *2*, 1900, 677.) From feces. Motile.

Bacillus fumigatus Migula. (No. 14, Lembke, Arch. f. Hyg., *29*, 1897, 320; Migula, Syst. d. Bakt., *2*, 1900, 679.) From feces. Motile.

Bacillus gazogenes Heurlin. (Heurlin, Bakt. Unters. d. Keimgehaltes im Genitalkanale der fiebernden Wöchnerinnen. Helsingfors, 1910, 97.) From the vagina.

Bacillus glacialis Migula. (Giftproduzierender Bacillus, Vaughan and Perkins, Arch. f. Hyg., *27*, 1896, 308; Migula, Syst. d. Bakt., *2*, 1900, 807.) From ice cream and cheese. Motile.

Bacillus involutus Wälsch. (Cent. f. Bakt., I Abt., Orig., *38*, 1905, 645.) From preputial secretion.

Bacillus laseri Migula. (Gasbildender aërober Bacillus, Laser, Cent., f. Bakt., *13*, 1893, 217; Migula, Syst. d. Bakt., *2*, 1900, 763.) From the lungs and liver of a calf. Motile.

Bacillus membranifer Migula. (No. 7, Lembke, Arch. f. Hyg., *26*, 1896, 302; Migula, Syst. d. Bakt., *2*, 1900, 675.) From feces. Motile.

Bacillus pseudotyphosus Migula. (Typhusähnlicher Bacillus, Lustig, Diag. d. Bakt. d. Wassers, 1893, 18; Migula, Syst. d. Bakt., *2*, 1900, 730; not *Bacillus pseudotyphosus* Kruse, in Flügge, Die Mikroorganismen, 3 Aufl., *2*, 1896, 383.) Motile. From several samples of water from Thales de Aosta, Italy.

Bacillus pulmonum Migula. (Proteus bei Lungengangrän des Menschen, Babes, Progrès médical roumain, April 6, 1889; Migula, Syst. d. Bakt., *2*, 1900,

755.) From gangrenous lung exudate and the spleen. Motile.

Bacillus radiatus Zimmermann. (Zimmermann, Bakt. unserer Trink- u. Nutzwässer, Chemnitz, *1*, 1890, 58; not *Bacillus radiatus* Lüderitz, Ztschr. f. Hyg., *5*, 1889, 149; not *Bacillus radiatus* Chester, Man. Determ. Bact., 1901, 241; *Bacillus aquatilis radiatus* Kruse, in Flügge, Die Mikroorganismen, 3 Aufl., *2*, 1896, 315; quoted as *B. radiatus aquatilis* Zimmermann by Kruse, *idem*; *Bacterium radiatus aquatilis* Chester, Ann. Rept. Del. Col. Agr. Exp. Sta., *9*, 1897, 100; *Bacterium aquatilis radiatus* Chester, *idem*; *Bacillus pseudoradiatus* Migula, Syst. d. Bakt., *2*, 1900, 830; *Bacterium aquatilis* Chester, Man. Determ. Bact., 1901, 160; not *Bacterium aquatile* Migula, *loc. cit.*, 469.) From water. Motile. In certain stages of development (presumably old cultures) Zimmermann states that this organism is Gram-negative.

Bacillus splendens Migula. (*Bacillus putidus splendens* Bernabei, Bull. d. Soc. Lancisiana d. Ospedali di Roma, *13*; see abst. in Cent. f. Bakt., *17*, 1895, 469; Migula, Syst. d. Bakt., *2*, 1900, 754.) From a case of fetid bronchitis. Motile.

Bacterium acidiformans (Sternberg) Chester. (*Bacillus acidiformans* Sternberg, Man. of Bact., 1893, 449; Chester, Ann. Rept. Del. Col. Agr. Exp. Sta., *9*, 1897, 79.) From the liver of a yellow fever patient. Also reported from beeswax (White, U. S. Dept. Agr. Bur. Entomol., Bull. 14, 1906, 14).

Bacterium cactivorum Pasmetti and Buzzati-Traverso. (Nuovo Gior. Bot. Ital., N.S. *42*, 1935, 117.) From a diseased cactus.

Bacterium dendrobii Pavarino. (Rev. di Pat. Veg., *5*, 1912, 242.) From *Dendrobium sp.*

Bacterium (?) musae (Gaumann) Elliott. (*Pseudomonas musae* Gaumann, Med. van het Inst. voor Plantz., No. 48, 1921, 58; Elliott, Manual Bact. Plant Path., 1930, 170; *Phytomonas (?) musae* Magrou, in Hauduroy et al., Dict. d. Bact. Path., 1937, 385.) From diseased bananas.

Bacterium nicotinovorum Bucherer. (Cent. f. Bakt., II Abt., *105*, 1942, 169.) From a mixture of soil, manure and mud.

Bacterium pseudotyphosum Migula. (Typhusähnlicher Bacillus, Lustig, Diagnostik der Bakterien des Wassers, 1893, 17; Migula, Syst. d. Bakt., *2*, 1900, 428.) Non-motile. Isolated by Sartori from Rome tapwater.

Bacterium teutlium Metcalf. (Metcalf, Cent. f. Bakt., II Abt., *13*, 1904, 28; *Aplanobacter teutlium* E. F. Smith, Intro. to Bact. Dis. of Plants, 1920, 474; *Phytomonas teutlia* Bergey et al., Manual, 3rd ed., 1930, 280.) From a soft rot of sugar beets. See Manual, 5th ed., 1939, 216 for a description of this species.

Flavobacterium dehydrogenans Arnaudi. (*Micrococcus dehydrogenans* Arnaudi, Boll. Sez. ital. Soc. intern. Microbiol., *18*, 1939, 000; Arnaudi, Cent. f. Bakt., II Abt., *105*, 1942–43, 352.) From a pressed yeast cake.

Flavobacterium vitarumen Knutsen. (Knutsen, in Bechdel, Honeywell, Dutcher and Knutsen, Jour. Biol. Chem., *80*, 1928, 234.) From the rumen of a cow.

Kurthia bessoni Severi. (Quoted from Giorn. Batteriol. e Immunol., *34*, 1946, 107.)

Kurthia variabilis Severi. (Giorn. Batteriol. e Immunol., *34*, 1946, 107.) From feces.

22. **Bacterium idoneum** McBeth. (McBeth, Soil Science, *1*, 1916, 460; *Cellulomonas idonea* Bergey et al., Manual, 1st ed., 1923, 165.) From Latin *idoneus*, capable.

Rods: 0.5 by 1.5 microns. Non-motile. Gram-negative.

Gelatin stab: Moderate, yellowish growth. Slight napiform liquefaction.

Agar colonies: Circular, convex, soft, becoming brittle, grayish, granular, entire.

Agar slant: Scant, yellowish-white growth, becoming distinctly yellow.

Gelatin stab: Moderate, yellowish growth. Slight napiform liquefaction.

Agar colonies: Circular, convex, soft, becoming brittle, grayish, granular, entire.

Agar slant: Scant, yellowish-white growth, becoming distinctly yellow.

Ammonia cellulose agar: Enzymatic zone shows a diameter of 2 to 3 mm at the end of 30 days.

Peptone cellulose agar: Enzymatic zone shows a diameter of 1.5 to 2.0 mm at the end of 30 days.

Broth: Turbid.

Filter paper broth: Paper reduced to thin, limp sheet which falls apart on slight agitation at end of 15 days.

Litmus milk: Acid, not digested.

Potato: Abundant, moist, glistening, grayish-white growth, becoming distinctly yellow.

Indole not formed.

Nitrites produced from nitrates.

Ammonia not produced.

Acid from glucose, maltose, lactose, starch and glycerol.

Aerobic, facultative.

Optimum temperature 20°C.

Source: Soil from California.

Habitat: Soil.

23. **Bacterium udum** Kellerman et al. (Kellerman, McBeth, Scales and Smith, Cent. f. Bakt., II Abt., *39*, 1913, 514; *Cellulomonas uda* Bergey et al., Manual, 1st ed., 1923, 166; *Proteus cellulomonas* var. *Proteus udus* Pribram, Klassifikation der Schizomyceten, Leipzig und Wien, 1933, 72.) From Latin *udus* growing in marshy ground.

Rods: 0.5 by 1.5 microns. Non-motile. Gram-negative.

Gelatin stab: Liquefaction.

Agar slant: Luxuriant, faintly yellowish growth.

Cellulose agar: Enzymatic zone 0.5 mm wide.

Broth: Turbid.

Litmus milk: Acid.

Potato: Good growth.

Indole not formed.

Nitrites produced from nitrates.

Ammonia is produced.

Acid from glucose, fructose, arabinose, xylose, maltose, lactose, sucrose, dextrin and starch.

Aerobic, facultative.

Optimum temperature 20°C.

Source: Compost from Arlington, Va.

Habitat: Soil.

24. **Bacterium lucrosum** McBeth. (McBeth, Soil Science, *1*, 1916, 461; *Cellulomonas lucrosa* Bergey et al., Manual, 1st ed., 1923, 167.) From Latin *lucrosus*, lucrative.

Rods: 0.4 by 1.3 microns. Non-motile. Gram-negative.

Gelatin stab: No growth.

Agar colonies: Circular, convex, semitransparent, granular, entire.

Agar slant: Moderate, flat, grayish-white growth, becoming somewhat iridescent.

Ammonia cellulose agar: On crowded plate, the colonies show an enzymatic zone of 1 mm or more.

Peptone cellulose agar: Enzymatic zone 2 to 3 mm wide in 25 days.

Broth: Turbid.

Filter paper broth: Paper is reduced to a grayish-white pulpy mass whose fibers separate on slight agitation.

Litmus milk: No change.

Potato: No growth.

Indole not formed.

Nitrites not produced from nitrates.

Ammonia not produced.

Acid from glucose, maltose, lactose, sucrose, starch and mannitol.

Aerobic, facultative.

Optimum temperature 20°C.

Source: Soil from California.

Habitat: Soil.

25. **Bacterium acidulum** Kellerman et al. (Kellerman, McBeth, Scales and Smith, Cent. f. Bakt., II Abt., *39*, 1913, 513; *Cellulomonas acidula* Bergey et al., Manual, 1st ed., 1923, 167.) From Latin *acidus*, acid.

Rods: 0.3 by 1.0 micron. Non-motile. Gram-negative.

Gelatin stab: No liquefaction.
Agar slant: Slight, grayish growth.
Cellulose agar: Enzymatic zone 0.5 to 1 mm in width.
Broth: Clear.
Litmus milk: Acid.
Potato: No growth.
Indole not formed.
Nitrites not produced from nitrates.
Ammonia not produced.
Acid from glucose, maltose, lactose and sucrose. None from glycerol or mannitol.
Starch not hydrolyzed.
Aerobic.
Optimum temperature 20°C.
Source: Soil from Utah.
Habitat: Soil.

26. **Bacterium castigatum** McBeth. (McBeth, Soil Science, *1*, 1916, 458; *Cellulomonas castigata* Bergey et al., Manual, 1st ed., 1923, 168.) From Latin *castigatus*, subdued.

Rods: 0.4 by 1.2 microns. Non-motile. Gram-negative.
Gelatin stab: Moderate surface growth. No liquefaction.
Agar colonies: Circular, slightly convex, brittle, grayish-white, granular, entire.
Agar slant: Abundant, glistening, grayish-white growth.
Ammonia cellulose agar: Enzymatic zone may attain a diameter of 2.5 mm in 30 days.
Peptone cellulose agar: Enzymatic zone may reach a diameter of 2 mm in 30 days.
Broth: Slightly turbid.
Filter paper broth: Paper completely disintegrated and reduced to a pulp-like mass in 15 days.
Litmus milk: Acid, not digested.
Indole not formed.
Nitrites not produced from nitrates.
Ammonia not produced.
Acid from glucose, maltose, lactose, sucrose, starch and glycerol.
Aerobic.
Optimum temperature 20°C.
Source: Soil from California.
Habitat: Soil.

27. **Bacterium bibulum** (McBeth and Scales) Holland. (*Bacillus bibulus* McBeth and Scales, Bur. of Plant Industry, U. S. Dept. of Agr., Bul. No. 266, 1913, 35; Holland, Jour. Bact., *5*, 1920, 217 and 221; *Cellulomonas bibula* Bergey et al., Manual, 1st ed., 1923, 158.) From Latin *bibulus*, thirsty.

Rods: 0.4 by 1.3 microns. Motile. Gram-negative.
Gelatin stab: Crateriform liquefaction.
Cellulose agar colonies: Circular, convex, smooth, soft, grayish to faintly yellowish-white, finely granular. Enzymatic zone 0.3 mm in some cases.
Agar slant: Luxuriant, glistening, smooth, moist, raised growth.
Broth: Slightly turbid.
Litmus milk: Faintly acid.
Potato: Smooth, glistening, canary yellow growth.
Indole is formed.
Nitrites not produced from nitrates.
Ammonia is produced.
Acid from glucose, maltose, lactose, sucrose, starch, glycerol and mannitol.
Aerobic, facultative.
Optimum temperature 20°C.
Source: From sewer slimes and cultivated soils.
Habitat: Soil.

Appendix I: The genus *Cellulomonas* as originally proposed was based on a single physiological property and included such diverse types of bacteria as (1) polar flagellate species, now placed in *Pseudomonas*, (2) Gram-variable, non-motile rods now placed in *Corynebacterium*, and (3) peritrichous, non-spore-forming, Gram-negative rods. Unfortunately the name is unsuitable for the third of these groups so that it has not been inserted in the outline used in this edition of the MANUAL. Descriptions of species previously placed in this genus are given below.

Genus A. Cellulomonas *Bergey et al.*

(Manual, 1st ed., 1923, 154.)

Small rods, with rounded ends, non-spore-forming, motile with peritrichous flagella, occurring in soil and having the property of digesting cellulose. Growth on ordinary culture media often not vigorous. Gram-negative.

The type species is *Cellulomonas biazotea* (Kellerman) Bergey et al.

Key to the species of genus Cellulomonas.

I. Motile with peritrichous flagella.
  A. Gelatin liquefied. Chromogenic.
    1. Milk acid.
      a. Ammonia not produced; indole not formed.
        1. *Cellulomonas biazotea.*
    2. Milk acid; digested.
      a. Ammonia produced; indole not formed.
        2. *Cellulomonas aurogenes.*
      aa. Ammonia produced; indole formed.
        3. *Cellulomonas galba.*
    3. Milk alkaline.
      a. Ammonia produced; indole not formed.
        4. *Cellulomonas folia.*
    4. Litmus milk unchanged.
      a. Ammonia produced; indole not formed.
        5. *Cellulomonas flava.*
  B. Gelatin liquefied. Non-chromogenic.
    1. Milk acid.
      a. Ammonia not produced; indole not formed.
        6. *Cellulomonas cellasea.*
      aa. Ammonia produced; indole not formed.
        7. *Cellulomonas iugis.*
      aaa. Ammonia not produced; indole formed.
        8. *Cellulomonas concitata.*
    2. Milk acid; digested.
      a. Ammonia produced; indole not formed.
        9. *Cellulomonas caesia.*
  C. Gelatin not liquefied. Chromogenic.
    1. Milk acid.
      a. Ammonia produced; indole formed.
        10. *Cellulomonas gilva.*
    2. Milk alkaline.
      a. Ammonia not produced; indole not formed.
        11. *Cellulomonas ferruginea.*
  D. Gelatin not liquefied. Non-chromogenic.
    1. Milk acid; not digested.
      a. Ammonia not produced; indole not formed.
        12. *Cellulomonas albida.*
        13. *Cellulomonas alma.*
      aa. Ammonia not produced; indole formed.
        14. *Cellulomonas desidiosa.*
      aaa. Ammonia produced; indole not formed.

15. *Cellulomonas pusilla.*
16. *Cellulomonas gelida.*

II. Motility not recorded.
A. Gelatin liquefied. Chromogenic.
1. Milk acid.
a. Ammonia not produced. Acid from glucose.
17. *Cellulomonas flavigena.*
aa. Ammonia produced. No acid from carbohydrates.
18. *Cellulomonas rossica.*

1. **Cellulomonas biazotea** (Kellerman et al.) Bergey et al. (*Bacillus biazoteus* Kellerman, McBeth, Scales and Smith, Cent. f. Bakt., II Abt., *39*, 1913, 506; Bergey et al., Manual, 1st ed., 1923, 158; *Proteus cellulomonas* var. *Proteus biazoteus* Pribram, Klassifikation der Schizomyceten, Leipzig und Wien, 1933, 72.)

This is the type species of the genus *Cellulomonas*.

Rods: 0.5 by 0.8 micron. Motile with one to three peritrichous flagella. Gram-negative.

Gelatin stab: Liquefaction.

Agar slant: Luxuriant yellow growth.

Cellulose agar: Enzymatic zone 0.25 mm or less in width.

Peptone cellulose agar: No enzymatic zone.

Broth: Turbid.

Litmus milk: Acid. No curdling or digestion.

Potato: Grows well.

Indole not formed.

Nitrites produced from nitrates.

Ammonia not produced.

Acid from glucose, maltose, lactose, sucrose, and glycerol. No acid from mannitol.

Aerobic, facultative.

Optimum temperature 20°C.

Source: Soil from Utah.

Habitat: Soil.

2. **Cellulomonas aurogenes** (Kellerman et al.) Bergey et al. (*Bacillus aurogenes* Kellerman, McBeth, Scales and Smith, Cent. f. Bakt., II Abt., *39*, 1913, 505; Bergey et al., Manual, 1st ed., 1923, 157.) From Latin and Greek, gold-producing.

Rods: 0.4 by 1.4 microns. Motile with one to three peritrichous flagella. Gram-negative.

Gelatin stab: Liquefaction.

Agar slant: Luxuriant yellow growth.

Cellulose agar: Enzymatic zone 0.5 to 1.5 mm wide.

Broth: Turbid.

Litmus milk: Acid, digested.

Potato: Luxuriant growth.

Indole not formed.

Nitrites produced from nitrates.

Ammonia produced.

Acid from glucose, maltose, lactose, sucrose, starch and glycerol. No acid from mannitol.

Aerobic, facultative.

Optimum temperature 20°C.

Source: From soil from Louisiana and Maine.

Habitat: Soil.

3. **Cellulomonas galba** (Kellerman et al.) Bergey et al. (*Bacillus galbus* Kellerman, McBeth, Scales and Smith, Cent. f. Bakt., II Abt., *39*, 1913, 509; Bergey et al., Manual, 1st ed., 1923, 157.) From Latin *galbus*, yellow.

Rods: 0.4 by 1.0 micron. Motile with one to three peritrichous flagella. Gram-negative.

Gelatin stab: Liquefaction.

Agar slant: Luxuriant yellow growth.

Cellulose agar: Enzymatic zone 0.5 mm in width.

Broth: Turbid.

Litmus milk: Acid, digested.

Potato: No growth.

Indole is formed.

Nitrites not produced from nitrates.

Ammonia produced.

Acid from glucose, maltose, lactose, sucrose, starch and glycerol. No acid from mannitol.

Aerobic, facultative.

Optimum temperature 20°C.

Source: Soil from Louisiana.

Habitat: Soil.

4. **Cellulomonas folia** Sanborn. (Jour. Bact., *12*, 1926, 1 and 343.) From Latin *folium*, leaf.

Description from Sanborn (Jour. Bact., *18*, 1929, 170) and also from his unpublished notes.

Rods: 0.8 to 1.0 by 1.0 to 1.5 microns, occurring singly and in short chains. Motile with four to six peritrichous flagella. Gram-negative.

Gelatin stab: Slow crateriform liquefaction, becoming stratiform.

Agar slant: Growth moderate, dirty-white, echinulate, raised, glistening, opaque, butyrous.

Broth: Turbid with yellowish sediment.

Litmus milk: Alkaline.

Potato: Thick, moist, yellowish-brown growth.

Indole not formed.

Nitrites produced from nitrates.

Acid and gas slowly produced from glucose, sucrose, glycerol and mannitol after prolonged incubation. No acid or gas from lactose.

Starch hydrolyzed.

Ammonia produced.

No H_2S formed.

Aerobic, facultative.

Optimum temperature 25° to 30°C.

Resembles *Cellulomonas rossica*.

Source: From decomposing leaves.

Habitat: Occurring in soil and active in decomposing leaves in composts, having the property of digesting cellulose.

5. **Cellulomonas flava** Sack. (Cent. f. Bakt., II Abt., *62*, 1924, 79.) From Latin *flavus*, yellow.

Rods: 0.2 by 1.5 microns. Motile. Gram-negative.

Gelatin colonies: Circular, citron yellow.

Gelatin stab: Very slow liquefaction.

Agar colonies: Large, circular, citron yellow.

Agar slant: Abundant, citron yellow streak.

Broth: Turbid with pellicle and sediment.

Litmus milk: Unchanged.

Potato: Light brown streak.

Indole not formed.

Nitrites and ammonia produced from nitrates.

Hydrogen sulfide produced.

Cellulose hydrolyzed.

Aerobic, facultative.

Optimum temperature 20°C.

Habitat: Soil.

6. **Cellulomonas cellasea** (Kellerman et al.) Bergey et al. (*Bacillus cellaseus* Kellerman, McBeth, Scales and Smith, Cent. f. Bakt., II Abt., *39*, 1913, 508; Bergey et al., Manual, 1st ed., 1923, 158.)

Rods: 0.5 by 1.2 microns. Motile with one to three peritrichous flagella. Gram-negative.

Gelatin stab: Liquefaction.

Agar slant: Limited grayish growth.

Cellulose agar: Enzymatic zone 0.5 mm or less.

Broth: Clear.

Litmus milk: Acid.

Potato: No growth.

Indole not formed.

Nitrites not produced from nitrates.

Ammonia not produced.

Acid from glucose, maltose, lactose, sucrose, starch, glycerol and mannitol.

Aerobic, facultative.

Optimum temperature 20°C.

Source: Soil from Utah.

Habitat: Soil.

7. **Cellulomonas iugis** (McBeth) Bergey et al. (*Bacillus iugis* McBeth, Soil Science, *1*, 1916, 456; Bergey et al., Manual, 1st ed., 1923, 158.) From Latin, joined together.

Rods: 0.4 by 1.4 microns. Motile with

one to three peritrichous flagella. Gram-negative.

Gelatin stab: Napiform liquefaction.

Agar colonies: Circular, convex, soft, grayish-white, granular, entire.

Agar slant: Scant, grayish-white, filiform growth.

Ammonia cellulose agar: After 20 days, all colonies show an enzymatic zone of 1 mm or more.

Peptone cellulose agar: Enzymatic zone continues to increase up to 30 days at which time it may reach 5 mm in width.

Broth: Turbid.

Filter paper broth: After 15 days, the paper shows many ragged holes but disintegrates readily.

Litmus milk: Acid, not digested.

Potato: Abundant, glistening, grayish-white growth.

Indole not formed.

Nitrites produced from nitrates.

Ammonia produced.

Acid from glucose, maltose, lactose, sucrose, starch, glycerol and mannitol.

Aerobic, facultative.

Optimum temperature 20°C.

Source: Soil from California.

Habitat: Soil.

8. **Cellulomonas concitata** (McBeth) Bergey et al. (*Bacillus concitatus* McBeth, Soil Science, *1*, 1916, 448; Bergey et al., Manual, 1st ed., 1923, 159.) From Latin *concitatus*, rapid.

Rods: 0.5 by 1.2 microns. Motile with one to four peritrichous flagella. Gram-negative.

Gelatin stab: Napiform liquefaction.

Agar colonies: Irregularly circular, decidedly convex, soft, becoming viscid, grayish-white, sometimes slightly fluorescent, granular, entire.

Agar slant: Abundant, flat, moist, faint yellowish-white growth.

Ammonia cellulose agar: Surface colonies show an enzymatic zone of 1.0 to 1.5 mm. Deep colonies no zone but colony somewhat clearer than surrounding medium.

Peptone cellulose agar: Enzymatic zone, surface colonies, 2 to 2.5 mm; bottom colonies, 1 mm or less.

Broth: Turbid.

Filter paper broth: In 15 days, the paper is a disintegrated fibrous mass which retains its pure white color.

Litmus milk: Acid, not digested.

Potato: No growth.

Indole is formed.

Nitrites not produced from nitrates.

Ammonia not produced.

Acid from fructose, maltose, lactose, sucrose, starch and glycerol.

Aerobic, facultative.

Optimum temperature 20°C.

Source: Soil from California.

Habitat: Soil.

9. **Cellulomonas caesia** (Kellerman et al.) Bergey et al. (*Bacillus caesius* Kellerman, McBeth, Scales and Smith, Cent. f. Bakt., II Abt., *39*, 1913, 507; *Cellulomonas caseia* (sic) Bergey et al., Manual, 1st ed., 1923, 159; *Cellulomonas casei* (sic) Bergey et al., Manual, 4th ed., 1934, 199.) From Latin *caesius*, bluish-gray.

Rods: 0.4 by 1.5 microns. Motile with one or two peritrichous flagella. Gram-negative.

Gelatin stab: Liquefaction.

Beef agar streak: Moderate, flat, thin growth, slightly bluish fluorescence.

Cellulose agar: Enzymatic zone, 0.5 to 1.0 mm in 15 days.

Broth: Turbid. Slight sediment in 5 days.

Litmus milk: Acid, digested.

Potato: No growth.

Indole not formed.

Nitrites produced from nitrates.

Ammonia produced.

Acid from glucose, maltose, lactose, sucrose, starch, glycerol and mannitol.

Aerobic, facultative.

Optimum temperature 20°C.

Source: Soil from Louisiana, Wisconsin and New Hampshire.

Habitat: Soil.

10. **Cellulomonas gilva** (McBeth) Bergey et al. (*Bacillus gilvus* McBeth, Soil Science, *1*, 1916, 453; Bergey et al., Manual, 1st ed., 1923, 160.) From Latin *gilvus*, pale yellow.

Rods: 0.5 by 1.5 microns. Motile with one to five peritrichous flagella. Gram-negative.

Gelatin stab: Moderate, yellowish-white surface growth. No liquefaction.

Agar colonies: Circular, convex, butyrous, canary-yellow, sometimes with brownish rings, granular, entire.

Agar slant: Filiform, yellowish-white growth.

Ammonia cellulose agar: Enzymic zone not more than 1 mm. Entire colony semitransparent.

Peptone cellulose agar: Enzymatic zone, 3 to 4 mm in 25 days.

Broth: Slightly turbid.

Filter paper broth: In 15 days, the paper is reduced to a thin, white filmy mass which disintegrates readily.

Litmus milk: Acid, not digested.

Potato: Abundant, canary-yellow growth.

Indole is formed.

Nitrites produced from nitrates.

Ammonia is produced.

Acid from glucose, maltose, lactose, sucrose, starch and glycerol. No acid from mannitol.

Aerobic, facultative.

Optimum temperature 20°C.

Source: Soil from California.

Habitat: Soil.

11. **Cellulomonas ferruginea** (Rullmann) Bergey et al. (*Bacillus ferrugineus* Rullmann, Cent. f. Bakt., I Abt., Orig., *24*, 1898, 465; van Iterson, Cent. f. Bakt., II Abt., *11*, 1904, 694; not *Bacillus ferrugineus* Rullmann, Cent. f. Bakt., I Abt., *24*, 1898, 467; Bergey et al., Manual, 1st ed., 1923, 150.) From Latin, rust-colored.

Rods: 0.5 to 0.8 by 1.5 to 2.0 microns, occurring singly. Motile, possessing peritrichous flagella. Gram-negative.

Gelatin colonies: Brown, the pigment diffusing into the medium.

Gelatin stab: No liquefaction.

Agar slant: Rusty-brown streak.

Broth: Turbid.

Litmus milk: Dark-yellow ring; alkaline.

Potato: Rusty-brown streak.

Indole not formed.

Nitrites not produced from nitrates.

Ammonia not produced.

Aerobic, facultative.

Optimum temperature 25°C.

Habitat: Water.

12. **Cellulomonas albida** (McBeth) Bergey et al. (*Bacillus albidus* McBeth, Soil Science, *1*, 1916, 445; Bergey et al., Manual, 1st ed., 1923, 160.) From Latin *albidus*, white.

Rods: 0.4 by 1.0 micron. Motile with one to three peritrichous flagella. Gram-negative.

Gelatin stab: Scant growth. No liquefaction.

Agar colonies: Circular, convex, soft, grayish-white, granular, entire.

Agar slant: Scant, white streak.

Ammonia cellulose agar: After 30 days the colonies show an enzymatic zone of 1 to 2 mm.

Broth: Clear.

Filter paper broth: In 15 days, the paper is reduced to a thin, filmy, grayish-white mass which readily breaks up.

Litmus milk: Slightly acid, not digested.

Potato: No growth.

Indole not formed.

Nitrites not produced from nitrates.

Ammonia not produced.

Acid from glucose, maltose, lactose, sucrose, starch, glycerol and mannitol.

Aerobic, facultative.

Optimum temperature 20°C.

Source: Soil from California.

Habitat: Soil.

13. **Cellulomonas alma** (McBeth) Bergey et al. (*Bacillus almus* McBeth, Soil Science, *1*, 1916, 446; Bergey et al.,

Manual, 1st ed., 1923, 161.) From Latin *almus*, nourishing.

Rods: 0.5 by 1.2 microns. Motile with one to five peritrichous flagella. Gram-negative.

Gelatin stab: Scant growth. No liquefaction.

Agar colonies: Circular, convex, soft, becoming brittle, grayish-white, granular, entire.

Ammonia cellulose agar: Enzymatic zone 3 to 4 mm in 25 days.

Peptone cellulose agar: Enzymatic zone 2.5 to 3.5 mm in 30 days.

Agar slant: Scant, grayish-white growth, becoming yellowish-white.

Broth: Slightly turbid.

Filter paper broth: Paper reduced to a loose felt-like white mass in 15 days.

Litmus milk: Slightly acid, not digested.

Potato: No growth.

Indole not formed.

Nitrites not produced from nitrates.

Ammonia not produced.

Acid from glucose, maltose, lactose, sucrose, starch and glycerol. No acid from mannitol.

Aerobic, facultative.

Optimum temperature 20°C.

Source: Soil from California.

Habitat: Soil.

14. **Cellulomonas desidiosa** (McBeth) Breed. (*Bacillus desiduosus* (sic) McBeth, Soil Science, *1*, 1916, 450; *Cellulomonas deciduosa* (sic) Bergey et al., Manual, 1st ed., 1923, 162; Breed, in Manual, 5th ed., 1939, 495.) From Latin *desidiosus*, inactive.

Rods: 0.4 by 1.0 micron. Motile with one to three peritrichous flagella. Gram-negative.

Gelatin stab: Moderate growth. No liquefaction.

Agar colonies: Circular, slightly convex, soft, becoming somewhat viscid, grayish-white, granular, entire.

Agar slant: Scant, flat, grayish-white growth.

Ammonia cellulose agar: Enzymatic zone 3 to 3.5 mm in 25 days.

Peptone cellulose agar: Enzymatic zone 1 to 2 mm around surface colonies. Bottom colonies frequently show no enzymatic zone until after 20 days.

Broth: Slightly turbid.

Filter paper broth: Paper is divided into gray white mass which readily disintegrates.

Litmus milk: Acid, not digested.

Potato: No growth.

Indole is formed.

Nitrites produced from nitrates.

Ammonia not produced.

Acid from glucose, lactose, maltose and starch. No acid from mannitol, sucrose or glycerol.

Aerobic, facultative.

Optimum temperature 20°C.

Source: Soil from California.

Habitat: Soil.

15. **Cellulomonas pusilla** (Kellerman et al.) Bergey et al. (*Bacillus pusilus* (sic) Kellerman, McBeth, Scales and Smith, Cent. f. Bakt., II Abt., *39*, 1913, 513; *Cellulomonas pusila* (sic) Bergey et al., Manual, 1st ed., 1923, 161.) From Latin *pusilla*, very small.

Rods: 0.6 by 1.1 microns. Motile with one to three peritrichous flagella. Gram-negative.

Gelatin stab: No liquefaction.

Agar slant: Scant, grayish-white growth.

Cellulose agar: Enzymatic zone 1 mm or less in width.

Broth: Turbid.

Litmus milk: Acid.

Potato: No growth.

Indole not formed.

Nitrites produced from nitrates.

Ammonia is produced.

Acid from glucose, maltose, lactose, sucrose, starch and glycerol. No acid from mannitol.

Aerobic, facultative.

Optimum temperature 20°C.

Source: Soil from District of Columbia and South Carolina.

Habitat: Soil.

16. **Cellulomonas gelida** (Kellerman et al.) Bergey et al. (*Bacillus gelidus* Kellerman, McBeth, Scales and Smith, Cent. f. Bakt., II Abt., *39*, 1913, 510; Bergey et al., Manual, 1st ed., 1923, 162.) From Latin *gelidus*, stiff.

Rods: 0.4 by 1.2 microns. Motile with one to three peritrichous flagella. Gram-negative.

Gelatin stab: No liquefaction.

Agar slant: Luxuriant, grayish-white growth.

Cellulose agar: Enzymatic zone 1.5 mm in width.

Broth: Turbid.

Litmus milk: Acid, peptonized.

Potato: Grows well.

Indole not formed.

Nitrites not produced from nitrates.

Ammonia is produced.

Acid from glucose, maltose, lactose, sucrose, starch and glycerol. No acid from mannitol.

Aerobic, facultative.

Optimum temperature 20°C.

Source: Soil from Connecticut.

Habitat: Soil.

17. **Cellulomonas flavigena** (Kellerman and McBeth) Bergey et al. (*Bacillus flavigena* Kellerman and McBeth, Cent. f. Bakt., II Abt., *34*, 1912, 488; Bergey et al., Manual, 1st ed., 1923, 165.) From Latin, yellow-producing.

Rods: 0.4 by 1.0 micron. Motility not recorded. Gram-negative.

Gelatin stab: Liquefaction.

Agar slant: Luxuriant, yellow growth.

Cellulose agar: Enzymatic zone 0.75 to 1.5 mm in width.

Broth: Turbid.

Litmus milk: Acid.

Potato: Grows well.

Indole not formed.

Nitrites produced from nitrates.

Ammonia not produced.

Acid from glucose, fructose, arabinose, xylose, maltose, lactose, sucrose, dextrin, starch, inulin, salicin, glycerol and mannitol.

Aerobic, facultative.

Optimum temperature 20°C.

Source: From contaminated culture.

Habitat: Soil.

18. **Cellulomonas rossica** (Kellerman and McBeth) Bergey et al. (*Bacillus rossicus* Kellerman and McBeth, Cent. f. Bakt., II Abt., *34*, 1912, 492; Bergey et al., Manual, 1st ed., 1923, 157; *Proteus cellulomonas* var. *Proteus rossicus* Pribram, Klassifikation der Schizomyceten, Leipzig und Wien, 1933, 72.)

Rods: 0.3 by 1.2 microns. Motility not recorded. Gram-negative.

Gelatin stab: Rapid liquefaction.

Agar slant: Luxuriant, yellow growth.

Cellulose agar: Enzymatic zone 0.5 to 1.0 mm in width.

Broth: Turbid.

Litmus milk: Alkaline.

Potato: Grows well.

Indole not formed.

Nitrites produced from nitrates.

Ammonia produced.

No acid from carbohydrate media.

Aerobic, facultative.

Optimum temperature 20°C.

Source: From contaminated culture.

Habitat: Soil.

Appendix II: The following cellulose-digesting bacteria are not included above:

Achromobacter picrum Fuller and Norman. (Jour. Bact., *46*, 1943, 276.) From soil.

Bacillus aurogenes var. *albus* Kellerman, McBeth, Scales and Smith. (Cent. f. Bakt., II Abt., *39*, 1913, 506.) From soil from New York State. Differs from *Cellulomonas aurogenes* in that it shows no chromogenesis.

Bacillus rossicus var. *castaneus* Kellerman et al. (*loc. cit.*, 508; *Proteus cellulomonas* var. *Proteus castaneus* Pribram, Klassifikation der Schizomyceten, Leipzig und Wien, 1933, 72.) From soils

from Maine, Connecticut and New York. Peritrichous. No liquefaction of gelatin. Chestnut color on potato.

Bacillus subalbus Kellerman et al. (*loc. cit.*, 512). From soils from Georgia, Kentucky and New York.

Bacillus subalbus var. *batatatis* Kellerman et al. (*loc. cit.*, 513). From soil from South Carolina. Differs from the above species in that it liquefies gelatin and forms a very scant yellowish growth on potato.

Appendix III: The following genus has been proposed for Gram-negative rods that utilize bacterial polysaccharides as a sole source of carbon.

Genus A. **Saccharobacterium** *Sickles and Shaw.*

(Jour. Bact., *28*, 1934, 430.)

Pleomorphic, non-motile, non-spore-forming rods. Gram-negative. Grow in mineral solutions containing bacterial polysaccharides as the sole source of carbon. Found in swamp and other uncultivated soils. Placed by the authors in the Family *Mycobacteriaceae* because of resemblances between these bacteria and those placed in *Cytophaga*, *Cellfalcicula* and *Cellvibrio*. As the latter genera are no longer placed in this family, *Saccharobacterium* is placed temporarily in this appendix to the genus *Bacterium* near bacteria that decompose cellulose and agar.

The type species is *Saccharobacterium ovale* Sickles and Shaw.

1. **Saccharobacterium ovale** Sickles and Shaw. (Jour. Bact., *28*, 1934, 422.) From Latin *ovum*, egg, ellipse.

Extremely pleomorphic. Young cells ellipsoidal, 1.5 by 2.0 microns, usually in pairs, contain granules which stain deeply with basic dyes. Older cultures contain cells which may be from 12 to 15 microns long. Non-motile. Gram-negative.

No growth on ordinary media such as beef-extract agar, blood agar, beef-extract agar slants, nutrient gelatin, potato slants, litmus milk, beef-infusion broth and beef-extract peptone broth.

Medium A plus pneumococcus II carbohydrate and 0.8 per cent agar: Very small, round, pink colonies, pinpoint in size after about 5 days. After 2 weeks 1 mm in diameter. Coherent.

Litmus milk: No growth.

Beef-extract peptone with 1 per cent sucrose: Moderate turbidity. Yellowish sediment.

Starch: Hydrolyzed in Medium A containing pneumococcus II carbohydrate.

Growth in lactose and sucrose broths. Growth in maltose, xylose and dextrin broths in some strains. No acid from inulin, mannitol, salicin and glucose broths.

Aerobic.

Minimum temperature 20°C. Optimum 34° to 35°C. Maximum 37°C. Thermal death point 54°C for 10 minutes.

Minimum pH 6.4. Optimum pH 7.0 to 7.4. Maximum pH 7.8.

Distinctive characters: The addition of 0.5 per cent sodium chloride to any favorable medium completely prevents growth of the organism (Medium A is that used by Dubos and Avery in 1931, $(NH_4)_2SO_4$, 1 g, K_2HPO_4, 2.0 g, tap water 1000 ml). Decomposes the carbohydrate of pneumococcus type II.

Source: Swamps and other uncultivated soils.

Habitat: Soil.

2. **Saccharobacterium acuminatum** Sickles and Shaw. (Jour. Bact., *28*, 1934, 425.) From Latin *acuminare*, to sharpen.

Extremely pleomorphic. Young organisms are pointed, often curved rods,

0.5 by 2 microns, having a densely staining granule. The tapering pointed ends remain unstained. Older cells have rounded ends, are spherical, pear-shaped or a long ellipsoid, stain weakly. Non-motile. Gram-negative.

No growth on ordinary media. See preceding species.

Medium S with pneumococcus I carbohydrate and 0.8 per cent agar: Very tiny, pale yellow colonies. Less than 0.5 mm in diameter.

Starch not hydrolyzed.

Growth in sucrose broth. No growth in glucose, lactose, maltose, dextrin, inulin, mannitol and salicin broths.

Aerobic.

Minimum temperature 20°C. Optimum 28° to 32°C. Maximum 34°C. Thermal death point 48°C for 10 minutes.

Minimum pH 6.0. Optimum pH 6.6 to 7.2. Maximum pH 7.8.

Distinctive characters: Decomposes the carbohydrate of pneumococcus Type I. The addition to any favorable medium of 0.7 per cent sodium chloride, of 0.3 per cent beef extract or of 0.5 per cent peptone completely inhibits growth.

The composition of Medium S is as follows: $MgSO_4 \cdot 7H_2O$, 0.2 g, $NH_4H_2PO_4$, 1.5 g, $CaCl_2$, 0.1 g, $FeCl_3$, tr, KCl, 0.1 g, 10 cc N/1 NaOH. Distilled water 1,000 ml, pH 7.2 to 7.4. To this was added the specific pneumococcus carbohydrate as a source of carbon in concentrations varying from 0.002 to 0.01 per cent.

Source: From swamps and other uncultivated soils.

Habitat: Soil.

28. **Bacterium nenckii** Biernacki. (Biernacki, Cent. f. Bakt., II Abt., *29*, 1911, 166; *Achromobacter nenckii* Bergey et al., Manual, 3rd ed., 1930, 227.) Named for Nencki, a chemist at the Medical Institute in Warsaw.

Rods: 0.8 by 1.25 to 2.0 microns, with rounded ends, occurring singly and in pairs. Capsulated. Non-motile. Gram-negative.

Gelatin colonies: Circular, convex, yellowish-white, granular.

Glucose and sucrose gelatin: Colonies larger and slimy.

Gelatin stab: No liquefaction.

Agar colonies: Circular, grayish-white, glistening, concentric, finely granular.

Agar slant: The medium is liquefied.

Glucose and sucrose agar: Heavy slimy growth with gas. Faint fruity odor.

Broth: Slightly turbid with gray sediment and slight odor.

Litmus milk: Acid and gas formation.

Potato: Slight growth.

Glycerol potato: Heavy growth with the appearance and consistency of cream.

Indole not formed.

Nitrites not produced from nitrates.

Acid and gas from glucose, fructose, galactose, maltose, sucrose, raffinose and mannitol.

Fruity odor in cultures.

Facultative anaerobe.

Optimum temperature 37°C.

Source: From Spanish dried grapes.

Habitat: Unknown.

29. **Bacterium polysiphoniae** Lundestad. (Lundestad, Cent. f. Bakt., II Abt., *75*, 1928, 331; *Flavobacterium polysiphoniae* Bergey et al., Manual, 3rd ed., 1930, 152.) From Greek, many tubes.

Rods: 0.5 to 0.6 by 2.0 to 4.0 microns, with rounded ends, occurring singly. Non-motile. Gram-negative.

Fish-gelatin colonies: Circular, slightly glistening, bright yellow, transparent, with denser center.

Fish-gelatin stab: Slight yellowish growth on surface. Slow saccate liquefaction.

Sea-weed agar colonies: Circular, flat, with concentric rings, diffuse margin, light yellow. Agar is disintegrated.

Fish-agar slant: Yellow, flat growth, with undulate margin.

Broth: Turbid with flocculent pellicle and yellowish sediment.

Indole not formed.

Nitrites not produced from nitrates.
No action on carbohydrates.
Slight hydrolysis of starch.
Aerobic, facultative.
Optimum temperature 30°C.
Source: Sea water of Norwegian Coast.
Habitat: Sea water.

30. **Bacterium droebachense** Lundestad. (Lundestad, Cent. f. Bakt., II Abt., 1928, 329; *Flavobacterium droebachense* Bergey et al., Manual, 3rd ed., 1930, 153; *Pseudomonas droebachense* Stanier, Jour. Bact., *42*, 1941, 544.) Latinized, from Dröbak, where this organism was isolated.

Rods: 0.5 to 0.6 by 2.0 to 2.6 microns, with rounded ends, occurring singly. Non-motile. Gram-negative.

Fish-gelatin colonies: Small, circular, compact, opaque, glistening, orange-yellow.

Fish-gelatin stab: Liquefaction infundibuliform becoming stratiform.

Sea-weed agar colonies: Small, circular, flat, opaque, glistening, orange-yellow. Agar is disintegrated.

Fish-agar slant: Flat, opaque, glistening, slimy, orange-yellow, entire growth.

Broth: Slight flocculent turbidity, yellow.

Indole not formed.

Nitrites not produced from nitrates.

Starch hydrolyzed.

Slow growth on surface of glucose agar stab. No gas.

Aerobic, facultative.

Optimum temperature about 37°C. Minimum temperature 5° to 10°C. Maximum 40°C.

Stanier (*loc. cit.*) identified cultures isolated from sea water on the Pacific Coast as belonging to this species. Some liquefied gelatin while others did not. Nitrates were reduced. A yellow membraneous pellicle was formed on broth, and the temperature range is given as 5° to 35°C. Optimum 25°C. He renamed the organism *Pseudomonas droebachensis*, but reported it non-motile.

Source: From sea water at Dröbak on the Norwegian Coast.

Habitat: Sea water.

31. **Bacterium delesseriae** Lundestad. (Lundestad, Cent. f. Bakt., II Abt., *75*, 1928, 332; *Flavobacterium delesseriae* Bergey et al., Manual, 3rd ed., 1930, 153.)

Rods: 0.5 to 0.6 by 1.6 to 2.6 microns, with rounded ends, occurring singly. Non-motile. Gram-negative.

Fish-gelatin colonies: Circular, transparent, glistening, concentrically ringed, yellow.

Fish-gelatin stab: Crateriform liquefaction, with yellow sediment.

Sea-weed agar colonies: Circular, flat, concentrically ringed, light yellow. Agar is disintegrated.

Fish-agar slant: No growth.

Broth: Turbid with flocculent pellicle and sediment, light yellow.

Indole not reported.

Nitrites not reported.

No action on carbohydrates.

Slight hydrolysis of starch.

Aerobic, facultative.

Optimum temperature 23°C.

Source: Sea water of Norwegian Coast.

Habitat: Sea water.

32. **Bacterium boreale** Lundestad. (Lundestad, Cent. f. Bakt., II Abt., *75*, 1928, 333; *Flavobacterium boreale* Bergey et al., Manual, 3rd ed., 1930, 154.) From Latin *borealis*, northern.

Rods: 0.5 to 0.6 by 1.6 to 2.6 microns, with rounded ends, occurring singly. Non-motile. Gram-negative.

Fish-gelatin colonies: Circular, opaque, glistening, concentrically ringed, yellow.

Fish-gelatin stab: Yellow, with crateriform liquefaction.

Sea-water agar colonies: Circular, flat, opaque, glistening, diffuse margin, light yellow. Agar is disintegrated.

Fish-agar slant: Yellow, flat, glistening, opaque, entire growth.

Broth: Finely flocculent, yellow sediment.

Indole not reported.

Nitrites not reported.

No action on carbohydrates.

Slight hydrolysis of starch.

Aerobic, facultative.

Optimum temperature 23°C.

Source: Sea water of Norwegian Coast.

Habitat: Sea water.

33. **Bacterium ceramicola** Lundestad. (Lundestad, Cent. f. Bakt., II Abt., *75*, 1928, 332; *Flavobacterium ceramicola* Bergey et al., Manual, 3rd ed., 1930, 154.) From Greek, living in earthenware.

Rods: 0.5 to 0.6 by 1.4 to 2.4 microns, with rounded ends, occurring singly and lying side-by-side. Non-motile. Gram-negative.

Fish-gelatin colonies: Circular, glistening, transparent, yellow.

Fish-gelatin stab: Slight, yellow surface growth. Liquefaction crateriform.

Sea-water agar colonies: Circular, flat, transparent, glistening, diffuse margin, light yellow. Agar is disintegrated.

Fish-agar slant: Moderate, yellow, flat, entire, glistening, opaque growth.

Broth: Light yellow pellicle and sediment.

Indole not reported.

Nitrites not reported.

No action on carbohydrates.

Slight hydrolysis of starch.

Aerobic, facultative.

Optimum temperature 23°C.

Source: Sea water of Norwegian Coast.

Habitat: Sea water.

34. **Bacterium rhodomelae** Lundestad. (Lundestad, Cent. f. Bakt., II Abt., *75*, 1928, 331; *Flavobacterium rhodomelae* Bergey et al., Manual, 3rd ed., 1930, 146.)

Rods: 0.5 to 0.8 by 1.2 to 2.0 microns, with rounded ends, occurring singly, in pairs, and at times in short chains. Motile. Gram-negative.

Fish-gelatin colonies: Circular, slightly glistening, opaque, white.

Fish-gelatin stab: Rapid infundibuliform liquefaction.

Sea-weed agar colonies: Circular, flat, thin, transparent, glistening, entire. Agar is dissolved.

Glucose agar slant: Moderate growth, white, becoming orange-yellow, flat, undulate margin, opaque, glistening.

Broth: Turbid, with pellicle and grayish-yellow, slimy sediment.

Indole not formed.

Nitrites not produced from nitrates.

No action on carbohydrates.

Very slight hydrolysis of starch.

Aerobic, facultative.

Optimum temperature 20° to 25°C.

Source: Sea water of Norwegian Coast.

Habitat: Sea water.

35. **Bacterium alginovorum** Waksman, Carey and Allen. (Jour. Bact., *28*, 1934, 215.) From M. L., alginic and Latin *voro*, devour.

Rods: 0.75 to 1.2 by 1.5 to 2.0 microns, with rounded to almost elliptical ends, especially when single, occurring frequently in pairs and even in chains. Actively motile. Capsule-forming. Gram-negative.

Alginic acid plate: Colony large, white in appearance with coarse granular center, entire margin. Clears up turbidity caused by the alginic acid on plate. No odor.

Alginic acid liquid medium: Heavy pellicle formation. Active production of an enzyme, alginase, which brings about the disappearance of alginic precipitate in sea water medium.

Salt water medium: A slimy pellicle of a highly tenacious nature is produced, the whole medium later turning to a soft jelly.

Sea water gelatin: Active and rapid liquefaction in two to six days, at 18°C;

highly turbid throughout the liquefied zone.

Agar liquefaction: Extensive softening of agar, no free liquid.

Sea water glucose broth: Abundant uniform turbidity, with surface pellicle; some strains give heavier turbidity and others heavier pellicle.

Litmus milk containing 3.5 per cent salt: No apparent growth.

Potato moistened with sea water: Moist, spreading growth, ivory-colored; heavy sediment in free liquid at the bottom.

Starch plate: Abundant, cream-colored, slimy growth; extensive diastase production.

Aerobic, microaerophilic.

Optimum temperature 20°C.

Source: From sea water, sea bottom sediments and from the surface of algal growth in the sea.

Habitat: Very common in the sea.

36. **Bacterium fucicola** Waksman, Carey and Allen. (Jour. Bact., *28*, 1934, 213.) From Latin *fucus*, seaweed and *cola*, dweller.

Short rods: 0.6 to 1.0 by 1.0 to 1.5 microns, with ends rounded to almost coccoid; slightly curved. Actively motile, with twirling motion. Gram-negative.

Alginic acid plate: Colonies finely granular, entire; at first whitish, turning brown in three to five days, and later almost black, producing a deep brown soluble pigment.

Alginic acid liquid medium: Limited growth on surface in the form of a pellicle. Frequently produces no growth at all.

Sea water gelatin: Active liquefaction; no growth in stab; thin, fluorescent growth throughout liquefied zone.

Agar liquefaction: Positive, although limited; only softening of agar.

Sea water glucose broth: Faint turbidity; no pellicle, no sediment.

Litmus milk containing salt: No apparent growth.

Potato moistened with sea water: No growth.

Starch plate: No growth.

Aerobic.

Optimum temperature 20°C.

Source: From sea water near the surface of the sand bottom.

Habitat: Rare in sea water.

Appendix I: Additional agar-digesting bacteria placed in genera other than *Bacterium*.

I. *Achromobacter*.
  A. Motile with peritrichous flagella.
    1. Nitrites produced from nitrates.
      1. *Achromobacter pastinatar*.

II. *Agarbacterium*.
  A. Non-motile.
    1. Nitrites produced from nitrates.
      2. *Agarbacterium bufo*.
  B. Motile, but position of flagella not recorded.
    1. Nitrites produced from nitrates.
      3. *Agarbacterium reducans*.
      4. *Agarbacterium viscosum*.
    2. Nitrites not produced from nitrates.
      5. *Agarbacterium mesentericus*.
      6. *Agarbacterium aurantiacum*.
      7. *Agarbacterium cyanoides*.
    3. Seven additional species that are numbered but not named.

III. *Flavobacterium.*
  A. Non-motile.
    1. Nitrites produced from nitrates.
      8. *Flavobacterium uliginosum.*
  B. Peritrichous flagella.
    1. Nitrites produced from nitrates.
      9. *Flavobacterium amocontactum.*

1. **Achromobacter pastinator** Goresline. (Jour. Bact., *26*, 1933, 442.) From Latin *pastinator*, one who digs a trench.

Short rods: 0.4 by 1.5 microns, occurring singly and in pairs. Motile with two to five peritrichous flagella. Gram-negative.

Plain gelatin stab: No growth.

Nutrient gelatin stab: Surface growth very scanty. No liquefaction.

Nutrient agar colonies: At first tiny, almost colorless, becoming yellowish and ring-like. Agar liquefied rapidly.

Nutrient agar slant: Growth good, flat, not thick. Agar liquefied along streak often to the depth of a quarter of an inch. Pocket formed at bottom of slant filled with a rather viscous, yellowish fluid.

Nutrient broth: Slight turbidity after 5 days. Subsurface but no surface growth. No sediment.

Litmus milk: Slightly acid after 20 days. No curd. Only a trace of reduction at bottom of tube.

Potato: No growth.

Indole not formed.

Nitrites produced from nitrates.

No H_2S produced.

Acid from arabinose, glucose, galactose, lactose, fructose, maltose, mannose, melezitose, pectin, raffinose, rhamnose, salicin, sucrose, starch and dextrin. No growth in dulcitol, erythritol, mannitol, sorbitol, glycerol, xylose and inulin.

Starch is hydrolyzed.

Limits of growth: pH 5.9 to 9.0.

Temperature relations: Optimum 28°C. Good growth at 25°C. Moderate growth at 20° and 37°C. No growth at 10° and 42°C.

Facultative anaerobe.

Distinctive characters: Digests agar rapidly; colonies sink through to the glass of the Petri dish. Fehling's solution reduced by the liquefied agar. Considerable change in viscosity of agar due to the digestion.

Source: From a trickling filter receiving creamery wastes.

Habitat: Probably widely distributed in nature.

2. **Agarbacterium bufo** Angst. (Puget Sound Biol. Sta. Pub., *7*, 1929, 49.)

Short rods with rounded ends, 0.6 by 0.8 micron, occurring singly and in pairs. Non-motile. No capsules. Gram-negative.

Fish gelatin stab: Stratiform liquefaction, growth best at top.

Fish gelatin colonies: Circular, crateriform, granular.

Fish agar slant: Abundant, filiform, raised, glistening, opaque, yellow, membranous growth.

Fish agar colonies: Circular, concentrically ringed, sunken, entire, granular, yellow to orange.

Digests agar; cellulose not attacked.

Potato: No growth.

Plain milk unchanged, surface growth yellow.

Does not produce H_2S or indole.

Nitrites produced from nitrates.

Acid from mannitol. No acid from xylose, rhamnose, arabinose, glucose, sucrose or lactose.

Starch not hydrolyzed.

Aerobic.

Optimum temperature 25° to 28°C. Maximum under 36°C.

Source: Isolated from *Odonthalia kamtschatica*.

Habitat: On marine algae.

3. **Agarbacterium reducans** Angst. (Puget Sound Biol. Sta. Pub., 7, 1929, 49.)

Short rods with rounded ends, 0.6 by 0.8 micron, occurring singly and in pairs. Motile. No capsules. Gram-negative.

Fish gelatin colonies: Circular, sunken, entire, crateriform, granular.

Fish gelatin stab: Crateriform liquefaction, growth only near surface.

Fish agar slant: Abundant, filiform, flat, glistening, smooth, opaque, white, butyrous growth.

Fish agar colonies: Moderate, circular, smooth, flat, entire, granular, white to buff or colorless.

Digests agar; cellulose not attacked.

Fish broth: Turbid, no sediment, no surface growth.

Potato: No growth.

Nitrites produced from nitrates.

No H_2S or indole formed.

Plain milk unchanged.

Acid from sucrose, arabinose, rhamnose and mannitol. No acid from xylose or lactose.

Starch is hydrolyzed.

Aerobic.

Optimum temperature 25° to 28°C; thermosensitive.

Source: Isolated from *Nercocystis luetkeana*.

Habitat: On marine algae.

4. **Agarbacterium viscosum** Angst. (Puget Sound Biol. Sta. Pub., 7, 1929, 49.)

Short rods with rounded ends, 0.6 to 0.8 micron, occurring singly or in pairs. Motile. No capsules. Gram-negative.

Fish gelatin colonies: Circular, sunken, entire, crateriform, granular.

Fish gelatin stab: Stratiform liquefaction, growth best at surface.

Fish agar slant: Abundant, raised, glistening, smooth, opaque, gray, vesicular, viscid growth.

Fish agar colonies: Circular, contoured, raised, lobate, granular, fluorescent green.

Digests agar; cellulose not attacked.

Fish broth: Flocculent pellicle, turbid, no sediment, fluorescent green.

Potato: Abundant, filiform, glistening, smooth, yellowish-brown, butyrous growth.

Nitrites produced from nitrates.

No H_2S or indole formed.

Plain milk unchanged; surface growth greenish.

No acid from rhamnose, sucrose, lactose, mannitol, xylose or arabinose.

Starch is hydrolyzed.

Aerobic.

Optimum temperature 20° to 28°C; thermosensitive.

Source: Isolated from *Iridaea cordata*.

Habitat: On marine algae.

5. **Agarbacterium mesentericus** Angst. (Puget Sound Biol. Sta. Pub., 7, 1929, 49.)

Short rods with rounded ends, 0.6 by 0.8 micron, occurring singly or in pairs. Motile. No capsules. Gram-negative.

Fish gelatin stab: Infundibuliform liquefaction; growth best at top.

Gelatin colonies: Circular, sunken, irregular, crateriform, granular.

Fish agar slant: Abundant, filiform, raised, glistening, finely wrinkled when old or dry, opaque, buff, membranous growth.

Fish agar colonies: Circular, concentrically ringed, flat, entire, granular, white to buff.

Digests agar; cellulose not attacked.

Fish broth: Membranous pellicle, moderate clouding, no sediment.

Potato: Spreading, raised, glistening, wrinkled, buff to yellowish, membranous growth.

Does not produce H_2S or indole.

Nitrites not produced from nitrates.

Plain milk unchanged.

Acid from mannitol. No acid from xylose, rhamnose, arabinose, glucose or lactose.

Starch is hydrolyzed.

Aerobic.

Optimum temperature 20° to 28°C; thermosensitive.

Source: Marine algae; isolated from *Nercocystis luetkeana.*

Habitat: On marine algae.

6. **Agarbacterium aurantiacum** Angst. (Puget Sound Biol. Sta. Pub., 7, 1929, 49.)

Short rods with rounded ends, 0.6 to 0.8 micron, occurring singly or in pairs. Motile. No capsules. Gram-negative.

Fish gelatin colonies: Circular, sunken, crateriform, entire.

Fish gelatin stab: Stratiform liquefaction, no growth along line of stab.

Fish agar slant: Abundant, filiform, flat, glistening, smooth, opaque, orange, butyrous growth.

Fish agar colonies: Circular, smooth, flat, erose, sunken, granular.

Digests agar; cellulose not attacked.

Fish broth: Membranous pellicle, turbid, no sediment.

Plain milk unchanged; surface growth orange.

Potato: Abundant, filiform, flat, dull, smooth, orange, butyrous growth.

Nitrites not produced from nitrates.

No H_2S or indole formed.

Acid from lactose and mannitol. No acid from xylose, rhamnose, arabinose, glucose or sucrose.

Starch not hydrolyzed.

Aerobic.

Optimum temperature 20° to 28°C; thermosensitive.

Source: Isolated from *Porphyra perforata.*

Habitat: On marine algae.

7. **Agarbacterium cyanoides** Angst. (Puget Sound Biol. Sta. Pub., 7, 1929, 49.)

Short rods with rounded ends, 0.8 by 1.4 microns, occurring singly or in pairs. Motile. No capsules. Gram-negative.

Fish gelatin colonies: Circular, sunken, entire, crateriform, granular.

Fish gelatin stab: Stratiform liquefaction, growth only at top.

Fish agar slant: Abundant, filiform, raised, glistening, smooth, opaque, gray, butyrous growth.

Fish agar colonies: Circular, smooth, flat, lobed, granular, greenish to yellowish.

Digests agar; cellulose not attacked.

Fish broth: Flocculent pellicle, turbid, no sediment, fluorescent green.

Potato: Abundant, filiform, raised, glistening, smooth, buff, butyrous growth.

Nitrites not produced from nitrates.

No H_2S or indole formed.

Plain milk acidified, greenish surface growth.

Acid from sucrose. No acid from xylose, arabinose, glucose, lactose, mannitol or rhamnose.

Starch is hydrolyzed.

Aerobic.

Optimum temperature 20° to 28°C; thermosensitive.

Source: Isolated from *Iridaea cordata.*

Habitat: On marine algae.

NOTE: Seven additional species are described with as much detail by Angst (*loc. cit.*) as are the six above species; but he refers to them only as *Agarbacterium* Nos. 5, 6, 7, 8, 9, 13, 14, and 15. All digest agar.

8. **Flavobacterium uliginosum** ZoBell and Upham. (Bull. Scripps Inst. of Oceanography, Univ. Calif., *5*, 1944, 263.) From Latin *uligo*, ooze or moist mud.

Rods: 0.4 to 0.6 by 1.2 to 3.9 microns, some slightly curved, occurring mostly singly with some short chains. Non-motile. Gram-negative.

All differential media except the fresh-water broth, litmus milk, and potato were prepared with sea water.

Gelatin colonies: 1 mm, orange, sunken.

Gelatin stab: Infundibuliform liquefaction. Yellow pigment. Gelatin discolored brown.

Agar colonies: Sunken, uneven, irregular, gummy colonies which liquefy agar. Produces orange to yellow pigment and discolors agar brown.

Agar slant: Luxuriant, yellowish-

orange, glistening, filiform, adherent growth which slowly liquefies agar.

Sea-water broth: Dense yellow pellicle, moderate turbidity, slightly viscid sediment.

Fresh-water broth: No visible growth.

Litmus milk: Completely decolorized, neutral.

Potato: No visible growth.

Indole not formed.

Nitrates rapidly reduced to nitrites.

Produces acid but no gas from xylose, glucose, maltose, lactose, sucrose and salicin. Does not ferment glycerol or mannitol.

Starch not hydrolyzed.

Hydrogen sulfide not formed.

Ammonia produced from peptone but not from urea.

Casein digested.

Fats not hydrolyzed.

Agar liquefied rapidly. However, after prolonged laboratory cultivation this organism gradually loses its ability to digest agar.

Aerobic, obligate.

Optimum temperature 20° to 25°C.

Source: Marine bottom deposits.

9. **Flavobacterium amocontactum** ZoBell and Allen. (Jour. Bact., *29*, 1935, 246.) From Latin *amo*, to love and *contactus*, touching, contacting.

Slender rods: 0.4 to 0.7 by 1.6 to 2.3 microns, with rounded ends, occurring singly and in irregular clumps. Stain very lightly. Possess well-defined capsules. Actively motile by means of peritrichous flagella. Gram-negative.

Gelatin stab: Good filiform growth with rapid saccate liquefaction.

Agar colonies: Circular, 2.0 to 4.0 mm in diameter, yellow.

Agar slant: Abundant, filiform, smooth, glistening, abundant, bright yellow growth having a butyrous consistency. Originally liquefied agar, but this property was lost following artificial cultivation.

Sea water broth: Good growth with ring at surface. Strong turbidity and abundant viscid sediment. No odor.

Milk: No growth.

Potato: No growth.

Potato dialyzed in sea water: Slight yellow growth.

Indole not formed.

Nitrites produced from nitrates.

Ammonia liberated from peptone.

Hydrogen sulfide produced.

No acid from glucose, lactose, sucrose, xylose or mannitol.

Starch not attacked.

Optimum reaction pH 8.0.

Optimum temperature 18° to 21°C.

Facultative aerobe.

Distinctive character: Adheres firmly to submerged glass slides; cannot be removed with running water.

Source: Many cultures isolated from glass slides submerged in sea water.

Habitat: Sea water.

Appendix II: Another species described recently is:

Bacillus exedens Wieringa. (Wieringa, Jour. Microbiol. and Serol., 7, 1941, 121; *Bacillus agar-exedens* Wieringa, *idem.*) From stable manure, leafmold and soil. Liquefies agar.

37. **Bacterium chitinophilum** Hock. (Jour. Marine Res., *4*, 1941, 103.) From M. L., chitin and Greek *philos*, loving.

Short rods: 0.35 to 0.65 by 0.95 to 1.5 microns. Motile. Gram-negative.

Sea water gelatin: Liquefaction; growth absent in stab but abundant in liquefied zone.

Sea water agar plate: Colonies circular, smooth, entire, raised, white.

Sea water liquid medium: Moderate growth, sometimes with formation of ring or pellicle. Scant granular sediment.

Decomposes natural chitinous material such as horseshoe crab shells and also purified chitin.

Four out of five strains produce nitrites from nitrates.

Acid from glucose and usually from sucrose, glycerol and mannitol. One of five cultures produced acid from lactose, Does not digest cellulose.

Does not hydrolyze starch.

Does not produce hydrogen sulfide.

Aerobic.

Optimum temperature 20°C.

Source: From the shell of a decomposing horseshoe crab, *Limulus polyphemus*, and from the intestinal tracts of *Venus mercenaria*, *Ovalipes ocellatus*, *Mustelus mustelus* and *Spheroides maculatus*.

Habitat: Common in marine sand, mud and water.

38. **Bacterium chitinochroma** Hock. (Jour. Marine Res., *4*, 1941, 105.)

Short rods: 0.45 to 0.75 by 0.90 to 1.4 microns. Motile. Gram-negative.

Sea water gelatin: Active liquefaction; no growth in stab, but thick bright yellow growth throughout the liquefied zone.

Basic agar plate: Colonies circular, smooth, entire, raised, varying in color from lemon to deep orange.

Basic liquid medium: Abundant growth with production of pellicle. Scant granular sediment, increasing with age of culture.

Decomposes natural chitinous material such as horseshoe crab shells and also purified chitin.

Does not produce nitrites from nitrates.

Acid from glucose and sucrose, but not lactose, glycerol and mannitol. Does not digest cellulose.

Hydrolyzes starch.

Does not produce hydrogen sulfide.

Aerobic.

Optimum temperature 20°C.

Source: From the intestinal tract of the squid, *Loligo pealeii*. Common.

Habitat: Marine sand, mud and water.

Appendix I: The first species of chitinovorous bacteria that was described and named was placed in the genus *Bacillus* because it was a motile rod.

1. *Bacillus chitinovorus* Benecke. (Bot. Zeitung, *63*, 1905, 227.) From M. L. *chitin*, chitin; *vorus*, devouring.

Rods: 0.75 by 2.0 microns. Sometimes in pairs and chains. Motile with peritrichous flagella. Gram-negative.

Gelatin stab: Liquefaction.

Mineral agar containing chitin: Good growth if no sugar is added to produce acid. Non-chromogenic.

Peptone mineral agar containing chitin: Good growth if reaction is neutral to slightly alkaline.

Salt in concentrations up to 1½ per cent is favorable for growth. Maximum 4 per cent.

Peptone broth: Turbid with heavy, slimy, whitish to brownish pellicle.

Nitrites produced from nitrates.

Ammonia produced in peptone-chitin media.

Acid from glucose and sucrose.

Optimum temperature 20°C.

Source: Isolated at Kiel from media containing decomposing crab shells and from media containing purified chitin; also from soil.

Habitat: Brackish water and soil.

NOTES: *Bacillus tumescens* Zopf, *Bacillus cohaerens* Gottheil, *Bacillus proteus vulgaris* Kruse, *Bacillus coli communis* Sternberg, *Bacillus fluorescens liquefaciens* Flügge, *Bacillus megatherium* De Bary, *Vibrio aquatilis* Günther and *Spirillum rubrum* von Esmarch did not attack chitin under the conditions tested by Benecke (*loc. cit.*).

Benton (Jour. Bact., *29*, 1935, 449) describes but does not name 17 types of chitinovorous bacteria isolated from water, mud and plankton of fresh water lakes, from decaying May fly nymph shells, intestinal contents of fish, frogs, bats, snipe, and crayfish. Also shore soil, composts, etc. Twelve types are reported to be monotrichous, two are peritrichous and three, position of flagella not stated. Of two Gram-positive types, one may have been a spore-former and the other a *Corynebacterium*. Two types digested cellulose.

ZoBell and Rittenberg (Jour. Bact., *35*, 1938, 275) isolated and studied but

did not name 31 cultures of chitinoclastic bacteria from marine sources. Out of 16 cultures studied intensively, all were Gram-negative. All but 4 of the 31 cultures were motile. One culture was a coccus and two species were vibrios. None digested cellulose.

*39. **Bacterium phosphoreum** (Cohn) Molisch. (*Micrococcus phosphoreus* Cohn, see letter addressed to J. Penn, Verzameling van stukken betreffende het geneeskundig staatstoezicht in Nederland, 1878, 126; *Bacterium phosphorescens* Fischer, Cent. f. Bakt., *3*, 1888, 107; *Photobacterium phosphorescens* Beijerinck, Arch. Néerl. d. Sci. Exactes, *23*, 1889, 401; *Streptococcus phosphoreus* Trevisan, I generi e le specie delle Batteriacee, 1889, 31; *Bacillus phosphoreus* Macé, Traité de Bact., Paris, 4th ed., 1901, 995; *Micrococcus phosphorescens* Chester, Man. Determ. Bact., 1901, 181; Molisch, Die Leuchtende Pflanzen, 1912, 66; *Photobacter phosphoreum* Beijerinck, Folia Microbiologica, Delft, *4*, 1916, 15; *Photobacterium phosphoreum* Ford, Textb. of Bact., 1927, 615.)

Description from Fischer (*loc. cit.*).

Coccobacilli: Occur frequently as zooglea. Non-motile. Stain lightly with aniline dyes.

Gelatin: No liquefaction.

Gelatin streak: Gray-white growth.

Broth: No growth.

Milk: No growth.

Potato: No growth.

Ferments carbohydrates.

Blue-green phosphorescence.

Minimum temperature 5°C. Maximum 25°. Optimum for luminescence 10°C.

Aerobic, facultative.

Source: Isolated from luminous fish.

Habitat: Found commonly on dead fish, meat, etc.

40. **Bacterium phosphorescens indigenus** (Eisenberg) Chester. (Einheimischer Leuchtbacillus, Fischer, Cent. f. Bakt., *3*, 1888, 107; *Photobacterium fischeri* Beijerinck, Arch. Néerl. d. Sci. Exactes, *23*, 1889, 401; *Bacillus fischeri* Trevisan, I generi e le specie delle Batteriacee, 1889, 18; *Bacillus phosphorescens indigenus* Eisenberg, Bakt. Diag., 3 Aufl., 1891, 124; *Vibrio fischeri* Lehmann and Neumann, Bakt. Diag., 1 Aufl., *2*, 1896, 342; Chester, Ann. Rept. Del. Col. Agr. Exp. Sta., *9*, 1897, 121; *Microspira fischeri* Chester, Man. Determ. Bact., 1901, 333; *Spirillum phosphorescens* Holland, Jour. Bact., *5*, 1920, 225; *Vibrio phosphorescens* Holland, *ibid.*, 226; *Achromobacter fischeri* Bergey et al., Manual, 3rd ed., 1930, 220.)

Description from Fischer (*loc. cit.*).

Short thick rods: 0.4 to 0.7 by 1.3 to 2.1 microns, with rounded ends, occurring singly and in pairs. Motile. Stain with the usual aniline dyes.

Johnson, Zworykin and Warren (Jour. Bact., *46*, 1943, 167) made pictures with the electron microscope of a culture which they identify with this species. The organisms have a tuft of polar flagella, indicating that this species belongs in the genus *Pseudomonas*.

Gelatin stab: Liquefaction.

Gelatin colonies: Liquefaction. After one week, circular, 1 mm in diameter, entire.

Broth: No growth.

Milk: No growth.

Blood serum: No growth.

Potato: No growth.

Cooked fish: Abundant growth. Entire surface covered with a gray-white, slimy, phosphorescent mass.

Temperature relations: Minimum 5° to 10°C. Optimum 22°C.

Aerobic.

Source: From sea water at Kiel and from herring.

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* Dr. Frank H. Johnson, Dept. Bacteriology, Princeton Univ., Princeton, New Jersey, assisted in preparing the section on phosphorescent bacteria, May, 1946

Habitat: Live on dead fish and in sea water.

41. Bacterium hemophosphoreum Pfeiffer and Stammer. (Pfeiffer and Stammer, Ztschr. f. Morph. u. Oköl. d. Tiere, *20*, 1930, 136; *Brucella (?) haemophosphoreum* Pribram, Klassifikation der Schizomyceten, Leipzig und Wien, 1933, 67.)

Rods: 1.0 by 4.5 microns, the size varying with the medium. Seem to show bipolar staining.

Fish agar with 3 per cent sea salt: Good growth.

Litmus milk: Acid. Reduction.

Potato: Yellow growth, medium becoming orange.

Indole not formed.

Nitrites not produced from nitrates.

Acid from glucose, sucrose, lactose, maltose, galactose, mannitol and fructose.

Phosphorescent.

Pathogenic for other insects.

Source: Isolated from the blood of diseased larvae of the mealworm, *Tenebrio molitor*.

Habitat: From diseased insect larvae.

Appendix 1: The following phosphorescent species have been described in the literature. Many are incompletely described and they have been placed in various genera without adequate study.

Achromobacter argenteophosphorescens (Katz) Bergey et al. (*Bacillus argenteophosphorescens I*, Katz, Cent. f. Bakt., *9*, 1891, 157; *Bacterium argenteo-phosphorescens* Chester, Ann. Rept. Del. Col. Agr. Exp. Sta., *9*, 1897, 121; *Bacillus argenteo-phosphorescens* Migula, Syst. d. Bakt., *2*, 1900, 869; Photobacillus I, Miquel and Cambier, Traité de Bact., Paris, 1902, 881; Bergey et al., Manual, 3rd ed., 1930, 221.) From sea water in Elizabeth Bay, Sydney, Australia. Silver-white luminescence. Probably a variety of *Photobacterium fischeri* Beijerinck, according to Katz.

Achromobacter cyaneophosphorescens (Katz) Bergey et al. (*Bacillus cyaneophosphorescens* Katz, Cent. f. Bakt., *9*, 1891, 158; *Photobacterium cyaneum* Ludwig, according to Kruse, in Flügge, Die Mikroorganismen, 3 Aufl., *2*, 1896, 331; *Photobacterium cyano-phosphorescens* (sic) Ford, Textb. of Bact., 1927, 619; *Vibrio cyaneo-phosphorescens* Lehmann and Neumann, Bakt. Diag., 7 Aufl., *2*, 1927, 543; Bergey et al., Manual, 3rd ed. 1930, 221.) From sea water in Little Bay, near Sydney, Australia. Bluish-green luminescence. Identical with or similar to *Photobacterium indicum* Beijerinck, according to Katz.

Achromobacter luminosum Bergey et al. (*Bacillus argenteo-phorphorescens II*, Katz, Cent. f. Bakt., *9*, 1891, 157; *Bacterium argenteo-phosphorescens* Migula, Syst. d. Bakt., *2*, 1900, 435; Photobacillus II, Miquel and Cambier, Traité de Bact., Paris, 1902, 882; Bergey et al., Manual, 3rd ed., 1930, 226.) From fish obtained in the market. Greenish-silver luminescence.

Achromobacter phosphoreum (Migula) Bergey et al. (*Bacillus argenteo-phosphorescens liquefaciens* Katz, Cent. f. Bakt., *9*, 1891, 157; *Bacillus phosphoreus* Migula, Syst. d. Bakt., *2*, 1900, 867; Bergey et al., Manual, 3rd ed., 1930, 222.) From sea water along the coast near Sydney, Australia. Luminescence slight. Probably identical with *Photobacterium luminosum* Beijerinck.

Achromobacter phosphoricum (Migula) Bergey et al. (*Bacillus argenteo-phosphorescens III*, Katz, Cent. f. Bakt., *9*, 1891, 157; *Bacillus phosphoricus* Migula, Syst. d. Bakt., *2*, 1900, 870; Photobacillus III, Miquel and Cambier, Traité de Bact., Paris, 1902, 882; Bergey et al., Manual, 3rd ed., 1930, 223.) From cuttlefish (*Sepia sp.*) obtained in the fish market. Bluish-greenish-white luminescence.

Achromobacter smaragdinophosphorescens (Katz) Bergey et al. (*Bacillus smaragdino-phorphorescens* Katz, Cent. f. Bakt., *9*, 1891, 159; *Bacterium smaragdino phosphorescens* Chester, Ann. Rept.

Del. Col. Agr. Exp. Sta., *9*, 1897, 124; *Bacterium smaragdino-phosphorescens* Migula, Syst. d. Bakt., *2*, 1900, 435; *Bacterium smargadinum* (sic) Chester, Man. Determ. Bact., 1901, 181; Bergey et al., Manual, 3rd ed., 1930, 225.) From herring in a fish market in Sydney, Australia. Green luminescence. Probably identical with *Photobacterium phosphorescens* Beijerinck.

Bacillus fischeri Dyar. (Dyar, Ann. N. Y. Acad. Sci., *8*, 1895, 370; *Bacterium fischeri* Chester, Man. Determ. Bact., 1901, 165.) Dyar added to the confusion in the nomenclature of phosphorescent organisms by giving this name to four cultures received by him from the Kràl collection labeled *Photobacterium phosphorescens*, *Photobacterium balticum*, *Photobacterium fischeri* and *Photobacterium pflügeri*.

Bacterium chironomi Issatschenko. (Bulletin du Jardin Impérial botanique à St. Pétersbourg, *11*, 1911, 37; *Photobacterium chironomi* Issatschenko, *ibid.*, 43.) A phosphorescent bacterium from a genus of midges, *Chironomus*.

Bacterium giardi (Kruse) Billet. (Giard and Billet, Compt. rend. Soc. Biol., Paris, 1889, 593; *Photobacterium pathogenicum* Giard, quoted from Eijkmann, see abst. in Cent. f. Bakt., *12*, 1892, 656; *Photobacterium giardi* Kruse, in Flügge, Die Mikroorganismen, 3 Aufl., *2*, 1896, 333; *Bacillus phosphorescens giardi* Kruse, *idem; Bacterium phosphorescens giardi* Chester, Ann. Rept. Del. Col. Agr. Exp. Sta., *9*, 1897, 125; Billet, Bull. Sci. France et Belgique, *21*, 1898, 144; *Bacterium phosphorescens-giardi* Chester, Man. Determ. Bact., 1901, 182.) Pathogenic for marine crustaceans.

Bacterium hippanici Issatschenko (*loc. cit.*, 47). From fresh water fish.

Bacterium lucens (van Tieghem) Nüesch. (*Micrococcus lucens* van Tieghem; Nüesch, Karsten's Deutsche Flora, 1880; quoted from Ludwig, Cent. f. Bakt., *2*, 1887, 375.) From luminous meat. Considered identical with *Bacterium phosphoreum*.

Bacterium luminosus (Beijerinck) Chester. (*Photobacterium luminosum* Beijerinck, Arch. Néerl. d. Sci. Exactes, *23*, 1889, 401; *Vibrio luminosus* Beijerinck, Bot. Zeit., 1889, 763, according to Trevisan, I generi e le specie delle Batteriacee, 1889, 23; *Bacillus luminosus* DeToni and Trevisan, in Saccardo, Sylloge Fungorum, *8*, 1889, 982; Chester, Ann. Rept. Del. Col. Agr. Exp. Sta., *9*, 1897, 121; *Microspira luminosa* Migula, Syst. d. Bakt., *2*, 1900, 1015; *Photobacter luminosum* Beijerinck, Folia Microbiologica, Delft, *4*, 1916, 15.) From sea water.

Bacterium pelagia Dubois. (Dubois, Compt. rend. Acad. Sci., Paris, *107*, 1888, 502 and *111*, 1890, 363; *Bacillus pelagia* DeToni and Trevisan, in Saccardo, Sylloge Fungorum, *8*, 1889, 959.) Isolated from the surface of *Pelagiae noctilucae*.

Bacterium pfluegeri Ludwig. (Ludwig, Ztschr. f. wissensch. Mikrosk., *1*, 1884, 181; *Micrococcus pflügeri* Ludwig, Hedwigia, No. 3, 1884; *Arthrobacterium pflügeri* DeBary, 1887; *Photobacterium pflügeri* Beijerinck, Cent. f. Bakt., *8*, 1890, 617; *Bacterium phosphorescens pflugeri* Chester, Ann. Rept. Del. Col. Agr. Exp. Sta., *9*, 1897, 125.) From fish and meat. Considered identical with *Bacterium phosphoreum*.

Bacterium pholas Dubois. (Compt. rend. Acad. Sci., Paris, *107*, 1888, 502.) Isolated from *Pholadis dactyli*.

Bacterium phosphorescens Hermes. (Hermes, Sitzungsber. naturf. Freunde, April 19, 1887, quoted from Cent. f. Bakt., *2*, 1887, 404; *Bacillus hermesi* Trevisan, I generi e le specie delle Batteriacee, 1889, 18.) From sea water. Macé (Traité de Bact., Paris, 4th ed., 1901, 994) says this may be the same as *Micrococcus phosphoreus* Cohn. Emerald-green luminescence.

Bacterium phosphorescens gelidus (Eisenberg) Chester. (Phosphorescirenden Mikroorganismen, Forster, Cent. f.

Bakt., *2*, 1887, 337; *Bacillus phosphorescens gelidus* Eisenberg, Bakt. Diag., 3 Aufl., 1891, 182; Chester, Ann. Rept. Del. Col. Agr. Exp. Sta., *9*, 1897, 125.) From phosphorescent sea fish. Fischer (Cent. f. Bakt., *4*, 1888, 89) states that this organism is the same as his *Bacterium phosphorescens*.

Coccobacillus acropoma Yasaki and Haneda. (Yasaki and Haneda, 1936; quoted from Harvey, Living Light, Princeton, 1940, 33.) From a fish (*Acropoma japonicum*).

Coccobacillus coelorhynchus. (Studied by Hsu, Sei-i-kai Med. Jour., *56*, 1937, 1; quoted from Harvey, Annual Rev. of Biochem., *10*, 1941, 543.) From a deep-sea fish (*Coelorhynchus sp.*).

Coccobacillus ikiensis. (Quoted from Harvey, Living Light, Princeton, 1940, 263.)

Coccobacillus loligo Kishitani. (Kishitani, Proc. Imp. Acad. Tokyo, *4*, 1928, 69; quoted from Harvey, Living Light, Princeton, 1940, 35.) From the squid (*Loligo edulis*).

Micrococcus cyanophos. (Studied by Claren, Ann. d. Chemie, *535*, 1938, 122; quoted from Harvey, Living Light, Princeton, 1940, 184.)

Micrococcus physiculus. (Quoted from Harvey, Living Light, 1940, 34.) The cause of luminescence of a fish (*Physiculus japonicus*).

Microspira phosphoreum Yasaki. (Yasaki, see Sei-i-kai-zasshi, *45*, 1926; quoted from Harvey, Living Light, 1940, 239.) Caused luminescence of a fresh-water shrimp in Japan.

Photobacter hollandiae Beijerinck. (Proc. Sect. Sci., Kon. Akad. v. Wetensch., Amsterdam, *3*, 1900, 352.) Similar to *Photobacterium luminosum*.

Photobacter hollandicum Beijerinck. (Folia Microbiologica, Delft, *4*, 1916, 15.)

Photobacter hollandicum parvum Beijerinck. (Folia Microbiologica, Delft, *4*, 1916, 15.)

Photobacter splendidum Beijerinck. (Beijerinck, Proc. Sect. Sci., Kon. Akad. v. Wetensch., Amsterdam, *3*, 1900, 352; *Vibrio splendidus* Lehmann and Neumann, Bakt. Diag., 7 Aufl., *2*, 1927, 543; *Photobacterium splendidum*, quoted from Harvey, Living Light, Princeton, 1940, 204.) May be a variety of *Photobacterium indicum*.

Photobacter splendor maris Beijerinck. (Proc. Sect. Sci., Kon. Akad. v. Wetensch., Amsterdam, *3*, 1900, 352.) May be a variety of *Photobacterium indicum*.

Photobacterium Beijerinck. (Beijerinck, Arch. Néerl. d. Sci. Exactes, *23*, 1889, 401; *Photobacter* Beijerinck, Proc. Sect. Sci., Kon. Akad. v. Wetensch., Amsterdam, *3*, 1900, 352; *Photospirillum* Miquel and Cambier, Traité de Bact., Paris, 1902, 888; *Photomonas* Orla-Jensen, Jour. Bact., *6*, 1921, 271.) *Photobacterium phosphorescens* is the type species of this genus. See *Bacterium phosphoreum*. Several species are placed in this genus by Fischer.

Photobacterium annulare Fischer. (Fischer, Ergebnisse d. Plankton-Expedition d. Humboldt-Stiftung, *4*, 1894, 41; *Microspira annularis* Migula, Syst. d. Bakt., *2*, 1900, 1014.) From sea water.

Photobacterium balticum Beijerinck. (Einheimischer Leuchtbacillus, Fischer, Cent. f. Bakt., *3*, 1888, 105; Beijerinck, Akad. v. Wetenschappen, Afdeel. Natuurk., 2de Reeks, *7*, 1890, 239; see abst. in Cent. f. Bakt., *8*, 1890, 617; *Vibrio balticus* Lehmann and Neumann, Bakt. Diag., 1 Aufl., *2*, 1896, 341.) From water of the Baltic Sea. The relationship of *Photobacterium balticum* to *Bacterium phosphorescens indigenus* is not clear. The former species is based on a culture sent by Fischer to Beijerinck labeled Einheimischer Leuchtbacillus which Beijerinck considered to be different from his *Photobacterium fischeri*.

Photobacterium caraibicum Fischer. (Fischer, *loc. cit.*, 1894, 41; *Microspira caraibica* Migula, *loc. cit.*, 1015.) From sea water.

Photobacterium coronatum Fischer. (Fischer, *loc. cit.*, 41; *Microspira coronata*

Migula, *loc. cit.*, 1013.) From sea water.

Photobacterium degenerans Fischer. (Fischer, *loc. cit.*, 37; *Microspira degenerans* Migula, *loc. cit.*, 1015; *Bacillus degenerans* Beijerinck, Folia Microbiologica, Delft, I, 1912, 1.) From sea water.

Photobacterium delgadense Fischer. (Fischer, *loc. cit.*, 37; *Microspira delgadensis* Migula, *loc. cit.*, 1014.) From sea water.

Photobacterium glutinosum Fischer. (Fischer, *loc. cit.*, 41; *Microspira glutinosa* Migula, *loc. cit.*, 1014.) From sea water.

Photobacterium hirsutum Fischer (*loc. cit.*, 41). From marine fish.

Photobacterium papillare Fischer. (Fischer, *loc. cit.*, 41; *Microspira papillaris* Migula, *loc. cit.*, 1016.) From sea water.

Photobacterium sepiae. (Quoted from Doudoroff, Jour. Bact., *44*, 1942, 451, who obtained a culture so labeled which had come from Prof. Kluyver's collection at Delft.)

Photobacterium tuberosum Fischer. (Fischer, *loc. cit.*, 37; *Microspira tuberosa* Migula, *loc. cit.*, 1014; *Photobacter tuberculatum* Beijerinck, Folia Microbiologica, Delft, *4*, 1916, 15.) From sea water.

Pseudomonas toyamensis. (Quoted from Harvey, Living Light, Princeton, 1940, 263.)

Sarcina noctiluca Heller. (Heller, Arch. f. Physiol., path. Chem. u. Mikr., N.F., *6*, 1853–54, 44; see Harvey, Living Light, Princeton, 1940, 6.) From fish. Possibly the same as *Bacterium phosphoreum* Molisch.

42. **Bacterium erythrogloeum** Ruhland and Grohmann. (Cent. f. Bakt., II Abt., *61*, 1924, 256.) From Greek *erythros*, red and *glota*, glue.

Rods: 0.5 by 2.0 microns. Non-motile. Gram-negative.

Gelatin plate: Red, droplet-like colonies.

Gelatin stab: No liquefaction.

Agar plate: Red, droplet-like colonies.

Agar slant: Raised, non-spreading, glistening, brick-red growth.

Potato: Abundant, brick-red, warty.

Aerobic.

Facultative autotroph.

Oxidizes hydrogen in an inorganic medium under an atmosphere of H_2, O_2, and CO_2. Produces a pellicle on the inorganic liquid medium.

Source: Calcareous soil.

Habitat: Probably widely distributed in soil.

43. **Bacterium lentulum** Grohmann. (Cent. f. Bakt., II Abt., *61*, 1924, 256.)

Rods: 0.5 by 1 to 2 microns. Motile by long thin peritrichous flagella. Gram-negative.

Gelatin plate: Colonies appear like milk droplets.

Gelatin stab: No liquefaction.

Agar plate: Tough, ochre yellow colonies about 7 mm in diameter.

Agar streak: Parchment-like, folded, yellow streak about 1 cm broad.

Potato: Heavy, yellow growth.

Aerobic.

Facultative autotroph.

Oxidizes hydrogen in an inorganic medium under an atmosphere of H_2, O_2, and CO_2. Produces a heavy folded pellicle on the inorganic liquid medium.

Source: Soil poor in lime.

Habitat: Probably widely distributed in soil.

44. **Bacterium leucogloeum** Ruhland and Grohmann. (Cent. f. Bakt., II Abt., *61*, 1924, 256.) From Greek *leukos*, white and *glota*, glue.

Rods: 0.5 by 0.7 to 52 (?) microns. Motile by means of peritrichous flagella.

Gelatin stab: No liquefaction.

Agar streak: Wide, slimy, wet, ivory-colored growth.

Potato: Gray-brown slime.

Aerobic.

Facultative autotroph.

Oxidizes hydrogen in an inorganic medium under an atmosphere of H_2, O_2,

and CO_2. Produces a pellicle on the inorganic liquid medium.

Source: Calcareous soil.

Habitat: Probably widely distributed in soil.

*45. **Bacterium stewartii** Erw. Smith. (Sweet corn bacillus, Stewart, N. Y. Agr. Exp. Sta. Bul. 130, 1897, 423; *Pseudomonas stewarti* Smith, Proc. A. A. A. Sci., *47*, 1898, 422; Smith, Bact. in Rel. to Plant Dis., *3*, 1914, 89; *Aplanobacter stewarti* McCulloch, Phytopath., *8*, 1918, 440; *Bacillus stewarti* Holland, Jour. Bact., *5*, 1920, 220; *Phytomonas stewartii* Bergey et al., Manual, 1st ed., 1923, 192.) Named for F. C. Stewart, American plant pathologist.

Description from Smith, U. S. Dept. Agric., Div. Veg. Phys. and Path., Bul. 28, 1901.

Rods: 0.4 to 0.7 by 0.9 to 2.0 microns. Capsules. Non-motile (McCulloch, *loc. cit.*). Gram-negative.

Gelatin: No liquefaction.

Nutrient agar colonies: Small, round, yellow colonies.

Broth: Growth feeble with whitish ring and yellow precipitate.

Milk: Yellow ring but no visible action on the milk. Slightly acid.

Nitrites not produced from nitrates. McNew (Phytopath., *28*, 1938, 773) states that less virulent strains assimilate only organic nitrogen; those of intermediate virulence assimilate nitrogen from inorganic salts without reduction of nitrates to nitrites; virulent strains reduce nitrates to nitrites.

Hydrogen sulfide not formed.

Indole production slight or none.

Reduction of methylene blue in Dunham's solution feeble or doubtful.

Acid but no gas from glucose, galactose, sucrose, mannitol and glycerol. No acid from maltose. Acid from fructose, arabinose and xylose (McNew, *loc. cit.*).

Starch not hydrolyzed.

Optimum temperature 30°C. Maximum 39°C. Minimum 8°C.

Optimum pH 6.0 to 8.0. Limits about pH 4.5 to 8.5.

8 per cent salt restricts growth.

Strict aerobe.

Source: From wilted sweet corn.

Habitat: Pathogenic on corn, *Zea mays*. Sweet corn very susceptible and field corn slightly so.

46. **Bacterium tardicrescens** McCulloch. (McCulloch, Phytopath., *27*, 1937, 135; *Phytomonas tardicrescens* Burkholder, Phytopath., *27*, 1937, 617.) From Latin, slow growing.

Rods: 0.6 to 0.8 by 1.58 microns. Motile with a polar flagellum. Gram-negative.

Gelatin: No liquefaction.

Beef-extract agar colonies: Circular, mustard yellow, edges entire, 1 to 1.5 mm in diameter.

Broth: Light clouding.

Milk: Slightly alkaline. Clearing after 5 to 6 weeks.

Nitrites are produced from nitrates.

Indole not produced.

No H_2S produced or feebly so.

Acid but no gas from glucose, fructose, galactose, arabinose, xylose and rhamnose. Alkaline reaction from salts of citric, malic and succinic acid.

Starch is not hydrolyzed.

Not lipolytic (Starr and Burkholder, Phytopath., *32*, 1942, 603).

Optimum temperature 26°C. Maximum 32°C. Minimum 5°C (McCulloch. Phytopath., *28*, 1938, 648).

Optimum pH 6.5 to 7.5. Growth slight at 5.8 and 8.0 (McCulloch, *loc. cit.*).

No growth with 3 per cent salt (McCulloch, *loc. cit.*).

Aerobic.

Distinctive character: Very slow grower.

*The section covering species of interest to plant pathologists has been prepared by Prof. Walter H. Burkholder, Cornell Univ., Ithaca, New York, May, 1946.

Source: Isolated by McCulloch and by Burkholder from blighted iris leaves.

Habitat: Pathogenic on *Iris spp.*

47. **Bacterium albilineans** Ashby. (Ashby, Trop. Agr., Trinidad, *6*, 1929, 135; *Phytomonas albilineans* Magrou, in Hauduroy et al., Dict. d. Bact. Path., Paris, 1937, 326.) From Latin, producing white streaks.

Description taken from Martin, Carpenter and Weller, The Hawaiian Planters' Record, *36*, 1932, 184.

Rods: 0.25 to 0.3 by 0.6 to 1.0 micron, occurring singly or in chains. Motile with a polar flagellum. Grám-negative.

Agar colonies: After 7 to 10 days, minute transparent drops, moist, shining. Honey yellow to Naples yellow.

Gelatin: No liquefaction.

Milk: Growth, but no visible change in the milk.

No growth with ammonium salts, nitrates, or asparagine as a source of nitrogen.

No growth in peptone water without carbohydrates. Invertase secreted.

Starch is not hydrolyzed.

Optimum temperature about 25°C. Maximum 37°C.

Distinctive characters: Differs from *Xanthomonas vascularum* which produces a large gummy type of colony, and which is a very active organism biochemically. The two pathogens also differ in the type of lesion they produce on sugar cane.

Source: Isolated by D. S. North (Colonial Sugar Ref. Co., Sidney, N.S. Wales, Agr. Rept., *8*, 1926, 1) from white stripe and leaf scald of sugar cane in Australia.

Habitat: Vascular pathogen of sugar cane, *Saccharum officinarum.*

Appendix I: The following species have been described from diseased plant tissues but may not, in some cases at least, have been the cause of the disease.

Bacillus betae Migula. (Kramer, Oesterreich. landwirtsch. Centralb., 1891, Heft 2 and 3; Migula, Syst. d. Bakt., *2*, 1900, 779.) The cause of a disease of the sugar beet (*Beta vulgaris*).

Bac. caryophyllacearum Dufrenoy. (Compt. rend. Soc. Biol., Paris, *81*, 1918, 920; probably there is an earlier reference to this species.) On *Dianthus, Saponaria* and *Lychnis.*

Bacillus coffeicola Steyaert. (Rev. Zoo. et Bot. Afr., *22*, 1932, 137.) From nodules on coffee roots.

Bacillus lacerans Migula. (*Bacillus* α, Busse, Ztschr. f. Pflanzenkr., *7*, 18—, 72; Migula, Syst. d. Bakt., *2*, 1900, 780.) From diseased sugar beets.

Bacillus maculicola Delacroix. (Delacroix, Compt. rend. Acad. Sci. Paris, *140*, 1905, 680; *Bacterium maculicola* Stapp, in Sorauer, Handb. d. Pflanzenkrankheiten, 5 Aufl., *2*, 1928, 276; *Aplanobacter maculicola* Elliott, Manual Bact. Plant Path., 1930, 8; *Phytomonas nicotianae-tabaci* Magrou, in Hauduroy et al., Dict. d. Bact. Path., 1937, 386.) From diseased spots on leaves of tobacco.

Bac. nucleophyllus Dufrenoy. (Compt. rend. Soc. Biol., Paris, *81*, 1918, 920, *nomen nudum.*) On *Rhododendron ferrugineum.*

Bac. tritici Dufrenoy. (Compt. rend. Soc. Biol., Paris, *81*, 1918, 920, *nomen nudem*; not *Pseudomonas tritici* Hutchinson, India Dept. of Agr., Bact. Ser., *1*, 1917, 174.) On wheat.

Bacillus vitis Montemartini. (Rev. Patol. Veg., *6*, 1913, 175.) Pathogenic on the grape (*Vitis vinifera*).

Bacterium apii Brizi. (Lav. e Relaz. d. Reg. Staz. di Patol. Veg., Roma, Gennio-Giugno, 15, 1896 and Atti R. Accad. Naz. Lincei, Rend. Cl. Sc. Fis., Math. e Nat., Ser. 5, *6*, 1897, 233.) Motile. From rot of celery.

Bacterium betae Chester. (Bacterial parasite, Arthur and Golden, Indiana Agr. Exp. Sta., Bull. 39, 1892, 61; Chester, Ann. Rept. Del. Col. Agr. Exp. Sta., *9*, 1897, 128; *Bacillus arthuri* Migula, Syst. d. Bakt., *2*, 1900, 681.) Motile. From diseased sugar beet tubers.

Bacterium briosianum Pavarino.

(Atti del. R. Accad. Naz. Lincei, Rend. Cl. Sci. Fis., Math. et Nat., *20*, 1911, 161.) Motile. From lesions on the vanilla vine.

Bacterium castinicolum Cavara. (Rev. d. Pat. Veg., *7*, 1914, 5.) Motile. From chestnut canker.

Bacterium corylii Brzezinski. (Bull. Intern. Acad. des Sci. Cracovie, Cl. Sci. Math. e Nat., 1903, 139.) Motile. From diseased filbert trees.

Bacterium dendrobii Pavarino. (Rev. di Pat. Veg., *5*, 1912, 242.)

Bacterium dianthi Chester. (Parasitic bacteria, Arthur and Bolley, Purdue Univ. Agr. Exp. Sta., Bull. 59, 1896, 21; Chester, Ann. Rept. Del. Col. Agr. Exp. Sta., *9*, 1897, 106; *Bacillus dianthi* Chester, Man. Determ. Bact., 1901, 253; *Pseudomonas dianthi* E. F. Smith, U. S. Dept. Agr., Div. Veg. Phys. and Path., Bull. 28, 1901, 153.) Motile. From lesions on carnation leaves.

Bacterium fici Cavara. (Ist. Bot. del. R. Univ. di Catania, Atti Acad. Gioen., *18*, Mem. 14, 1905, 1; *Phytomonas* (?) *fici* Magrou, in Hauduroy et al., Dict. d. Bact. Path., 1937, 354.) Motile. Causes a blight of figs.

Bacterium lycopersici var. *vitiati* Strzalkowska. (Strzalkowska, Acta Soc. Bot. Poloniae, Warsaw, *7*, 1930, 611; *Phytomonas vitiati* Burkholder, in Manual, 5th ed., 1939, 216.) From rotting tomato.

Bacterium mali Brzezinski. (Bull. Intern. Acad. Sci. Cracovie, Cl. Sci. Math. e Nat., 1903, 100.) Motile. From apple canker.

Bacterium montemartinii Pavarino. (Rev. di Pat. Veg., *5*, 1911, 65.) Motile. From wisteria canker.

Bacterium (?) *oncidii* Peglion. (Peglion, 1899, quoted from Hauduroy et al., Dict. Bact. Path., 1937, 388; *Bacillus oncidii* Stevens, 1913; *Phytomonas* (?) *oncidii* Hauduroy et al., *idem.*) From an orchid (*Oncidium sp.*).

Bacterium pini Chester. (Bacillus des tumeurs du Pin d'Alep, Vuillemin, Compt. rend. Acad. Sci., Paris, *107*, 1888, 874 and 1184; *Bacillus vuillemini* Trevisan, I generi e le specie delle Batteriacee, 1889, 19; Chester, Ann. Rept. Del. Col. Agr. Exp. Sta., *9*, 1897, 127; *Pseudomonas pini* Petri, Ann. Ist. Supt. For. Naz. Firenze, *9*, 1924, 187.) From galls on pine (*Pinus halepensis*).

Bacterium putredinis Davaine. (Davaine, Bactéries, in Dictionnaire Encyclopédique des Sci. Médicales, 1866; *Bacillus putredinis* Trevisan, Add. ad Gen., p. 36; see DeToni and Trevisan, in Saccardo, Sylloge Fungorum, *8*, 1889, 1025; not *Bacillus putredinis* Weinberg, Nativelle and Prévot, Les Microbes Anaérobies, Paris, 1937, 755.) Causes a soft rot of several plants.

Bacterium pyri Brzezinski. (Bull. Internat. d. l'Acad. des Sci. de Cracovie, Cl. Sci. Math. e Nat., 1903, 130.) Motile. From pear canker.

Bacterium rubefaciens Burr. (Burr, Ann. App. Biol., *15*, 1928, 570; *Phytomonas rubefaciens* Magrou, in Hauduroy et al., Dict. Bact. Path., 1937, 406; not *Bacterium rubefaciens* Chester, Ann. Rept. Del. Col. Agr. Exp. Sta., *9*, 1897, 115.)

Bacterium suberfaciens Burr. (Burr, Ann. App. Biol., *15*, 1928, 570; *Phytomonas suberfaciens* Magrou, in Hauduroy et al., Dict. Bact. Path., 1937, 417.) Motile. From diseased potato tubers.

48. **Bacterium rubefaciens** (Zimmermann) Chester. (*Bacillus rubefaciens* Zimmermann, Die Bakterien unserer Trink- und Nutzwässer, Chemnitz, *1*, 1890, 26; Chester, Ann. Rept. Del. Col. Agr. Exp. Sta., *9*, 1897, 115; *Erythrobacillus rubefaciens* Holland, Jour. Bact., *5*, 1920, 223; *Serratia rubefaciens* Bergey et al., Manual, 1st ed., 1923, 92; *Chromobacterium rubefaciens* Topley and Wilson, Princ. Bact. and Immun., *1*, 1931, 402.)

From Latin *ruber*, red and *facio*, to make.

Rods: 1.0 to 1.6 microns in length, occurring singly and in pairs. Actively motile. Gram-negative.

Gelatin colonies: Minute, white.

Gelatin stab: Surface growth yellowish, the medium taking on a red tinge. No liquefaction.

Agar colonies: Small, white, with erose margin.

Agar slant: White, smooth, glistening, somewhat luxuriant, the medium taking on a wine red color.

Broth: Turbid with white pellicle, the medium slowly assuming a reddish tinge.

Litmus milk: Acid, with slow coagulation and reduction of the litmus. Becoming alkaline.

Potato: A heavy, white, creamy layer, which later becomes yellowish-brown.

Indole not produced.

Nitrites produced from nitrates.

Aerobic, facultative.

Optimum temperature 25°C. No growth at 37°C.

Habitat: Water.

49. **Bacterium rubidum** (Eisenberg) Chester. (*Bacillus rubidus* Eisenberg, Bakt. Diag., 3 Aufl., 1891, 88; *Bacterium rubidus* (sic) Chester, Ann. Rept. Del. Col. Agr. Exp. Sta., *9*, 1897, 107 and 115; *Serratia rubida* Levine and Soppeland, Iowa State Coll. Engineering Exp. Sta. Bull. 77, 1926, 53.) From Latin *rubidus*, red.

Description from Eisenberg (*loc. cit.*). Levine and Soppeland (*loc. cit.*) found an organism in buttermilk which they identified as *Serratia rubida*. Their description is more complete than that given by Eisenberg but differs from the original in several respects.

Rods: Medium size with rounded ends, often in long chains. Motile.

Gelatin colonies: Circular, finely granular, entire, with reddish center. Slow growth.

Gelatin stab: Liquefaction. Brownish-red sediment.

Agar colonies: Small, flat, smooth, amorphous, entire, brownish-red. Slow growth.

Agar slant: Brownish-red streak. Spreading over surface.

Potato: Brownish-red growth.

Blood serum liquefied, red pigment.

Aerobic, facultative.

Does not grow well at 37°C.

Source: Water.

50. **Bacterium latericeum** (Adametz) Lehmann and Neumann. (*Bacillus latericeus* Adametz, Die Bakterien der Trink- und Nutzwässer, Mitteil. der oestrr. Versuchsanst. f. Brauerei u. Mälzerei in Wien, 1888, 50; *Bacillus erythraeus* Trevisan, I generi e le specie delle Batteriacee, 1889, 19; *Bacterium latericeum* Lehmann and Neumann, Bakt. Diag., 1 Aufl., *2*, 1896, 258; *Serratia latericea* Bergey et al., Manual, 1st ed., 1923, 94.) From Latin *latericeus*, brick.

Rods: 0.5 to 0.7 by 1.0 to 1.3 microns. Non-motile. Gram-negative.

Gelatin colonies: Small, white, granular, with slightly irregular margin.

Gelatin stab: A thin, dry, spreading, cream-pink surface growth. No liquefaction.

Agar colonies: Dry, glistening, whitish, with irregular margin.

Agar slant: Brick-red, smooth, glistening, butyrous.

Broth: Thick pellicle; fluid clear.

Litmus milk: Alkaline.

Potato: Brick-red streak.

No gas from carbohydrate media.

Indole not produced.

Nitrites produced from nitrates.

Aerobic, facultative.

Optimum temperature 25° to 30°C.

Habitat: Water.

51. **Bacterium alginicum** Waksman, Carey and Allen. (Jour. Bact., 28, 1934, 213.)

Rods short to almost spherical, 0.6 to 1.0 micron in diameter. Sluggishly motile. Capsule-forming. Gram-negative.

Alginic acid plate: White, finely granulated colonies, with entire margin. Does not clear up the turbidity in plate. Odor formed, resembling that of old potatoes.

Alginic acid liquid medium: Thin pellicle, weak alginase formation.

Sea water gelatin: Thin growth throughout gelatin stab, no liquefaction in 7 days at 18°C.

Agar liquefaction: None.

Sea water glucose broth: Uniform but

very limited turbidity; no pellicle; no sediment.

Litmus milk containing salt: No apparent growth.

Potato moistened with sea water: Moist, spreading growth, cream-colored; heavy sediment in free liquid at bottom.

Starch plate: Limited, pale blue growth; no diastase.

Aerobic.

Optimum temperature 20°C.

Source: From sea water, and from the surface of algal growth.

Habitat: Common in sea water.

52. **Bacterium terrestralginicum** Waksman et al. (Waksman, Carey and Allen, Jour. Bact., *28*, 1934, 217.)

Long rods, with somewhat rounded ends, usually single, but also in pairs, and occasionally in chains of shorter rods. 1.0 to 1.5 by 1.5 to 2.5 microns. Motile. Granular. Gram-negative.

Alginic acid plate: Colonies small, whitish in appearance with a slight metallic sheen.

Alginic acid liquid medium: Medium at first clouded. Later, a pellicle is formed on the surface of the medium, which is soon broken up due to active gas formation. Reaction of medium becomes slightly alkaline.

Gelatin medium: Slow growth throughout stab, slow liquefaction at surface of medium at 18°C.

Agar liquefaction: None.

Glucose broth: Abundant turbidity, some sediment, no pellicle, slightly fluorescent.

Litmus milk: Acid, milk coagulated, only limited digestion of coagulum.

Potato: Abundant, pinkish, compact, dry growth on surface of plug, the rest of plug becoming gray, with a tendency to darkening.

Starch plate: Limited growth along streak, no diastase.

Aerobic to facultative anaerobic.

Optimum temperature 30°C.

Source: From New Jersey soil.

Habitat: Soil.

53. **Bacterium cygni** Migula. (Septikämiebacillus der Schwäne, Fiorentini, Cent. f. Bakt., *19*, 1896, 935; Migula, Syst. d. Bakt., *2*, 1900, 365; *Bacillus cygneus* Chester, Manual Determ. Bact., 1901, 221.) From Latin *cygnus*, swan.

Rods: Motile. Gram-negative.

This organism may have been the fowl cholera or septicemia organism (*Pasteurella avicida* Trevisan); but is more probably closely related to the organism which causes keel in ducklings (*Salmonella anatis* Rettger and Scoville).

Source: From a swan.

Habitat: The cause of an infectious disease of swans in the city park at Milan, Italy in 1895.

54. **Bacterium cyprinicida** Plehn. (Plehn, Cent. f. Bakt., I Abt., Orig., *35*, 1903–04, 461; *Klebsiella cyprinicida* Bergey et al., Manual, 2nd ed., 1925, 266.) From Greek *kyprmos*, carp and Latin *caedo*, to kill.

Rods: 0.8 by 1.0 micron, occurring singly and in chains. Capsulated. Non-motile. Gram-negative.

Gelatin colonies: White, glistening, convex, with slight fluorescence around the colony in three or four days.

Gelatin stab: White, convex surface growth. No liquefaction.

Agar slant: White, glistening layer, becoming slimy.

Broth: Turbid, with thick gray pellicle and slimy sediment.

Litmus milk: Slightly alkaline. No coagulation.

Potato: Light yellowish layer, becoming dark brownish. The medium is dark violet-gray.

Indole not formed.

Nitrites not produced from nitrates.

No acid from carbohydrate media.

Aerobic, facultative.

Optimum temperature 10° to 20°C.

Habitat: The cause of a fatal disease in carp, showing as red spots on the ventral surface.

55. **Bacterium parvulum** Conn. (N. Y.

Agr. Exp. Sta. Bul. 494, 1922, 26.) From Latin, very small.

Very small rods: 0.1 to 0.2 by 0.3 to 0.5 micron. Non-motile. Gram-negative.

Gelatin plate: Punctiform colonies.

Agar plate: Punctiform colonies.

Grows poorly in liquid media.

Indole not formed.

Nitrites produced from nitrates.

No acid from glucose, lactose, sucrose, glycerol or ethyl alcohol in either liquid or solid media.

Starch not digested.

Optimum temperature 25°C.

Strictly aerobic.

Distinctive character: Causes strong volatilization of ammonia from a mixture of horse feces and urine.

Source: From manure.

Habitat: Soil.

56. **Bacterium methylicum** (Loew) Migula. (*Bacillus methylicus* Loew, Cent. f. Bakt., *12*, 1892, 465; Migula, Syst. d. Bakt., *2*, 1900, 447.) From the chemical term, methyl.

Short, thick rods: 1.0 by 2.0 to 2.5 microns. Gram stain not recorded.

Gelatin colonies: After 2 days, round to oval, yellowish, entire; later edges ciliate. Liquefaction.

Glucose gelatin stab: Liquefaction crateriform. Whitish-yellowish sediment. No liquefaction in depth.

Glucose gelatin stab: In depth, little or no growth, slowly liquefied near surface.

Agar stab: Surface growth spreading, grayish-white. No growth in depth.

Broth: No turbidity. On the surface and adherent to the walls, a white ring which precipitates on shaking.

Potato: Growth very slow, pure white, adherent.

Grows well in 0.5 per cent methyl alcohol, 0.05 per cent dicalcium phosphate, and 0.01 per cent magnesium sulfate, on which broth it forms a reddish pellicle.

Possesses the ability to decompose formaldehyde and formic acid salts with formation of a reddish pellicle.

Aerobe.

Source: A culture contamination from the air.

Habitat: Probably soil.

Appendix I: A few of the numerous Gram-negative, motile or non-motile, non-spore-forming rods that do not belong in the groups previously listed in this genus are described here. All have been placed in the genus *Bacillus* by those who have described them, although none form spores.

I. Produce a pink to red chromogenesis.
  A. Motile.
    1. *Bacillus lactorubefaciens.*
  B. Non-motile.
    1. Gelatin liquefied.
      2. *Bacillus rubricus.*
      3. *Bacillus rufus.*
    2. Gelatin not liquefied.
      a. Salmon pink on agar.
        4. *Bacillus mycoides corallinus.*
      aa. Vinous red on agar.
        5. *Bacillus bruntzii.*
II. Produces a water-soluble orange to emerald green pigment.
  A. Motile.
    1. Gelatin liquefied.
      6. *Bacillus aurantiacus tingitanus*

1. **Bacillus lactorubefaciens** Gruber. (Gruber, Cent. f. Bakt., II Abt., *8*, 1902, 457; *Serratia lactorubefaciens* Bergey et al., Manual, 1st ed., 1923, 92.) From Latin, to make milk red.

Small rods: 0.4 to 0.6 by 3.5 microns, occurring singly and in pairs. Motile with peritrichous flagella. Gram reaction not given.

Gelatin colonies: Grayish-white, smooth, glistening, spreading.

Gelatin stab: At times arborescent; the medium tinged with red. No liquefaction.

Agar colonies: Circular, lobed, grayish, contoured.

Agar slant: White, spreading growth.

Broth: Turbid, with grayish pellicle and slimy sediment.

Limus milk: Becomes rose red, slimy, slightly acid, without coagulation.

Potato: White, spreading growth.

No gas from carbohydrate media.

Indole not produced.

Nitrites produced from nitrates.

Aerobic, facultative.

Optimum temperature 25°C.

Habitat: Milk.

2. **Bacillus rubricus** Hefferan. (Hefferan, Cent. f. Bakt., II Abt., *11*, 1903, 403; *Erythrobacillus rubricus* Holland, Jour. Bact., *5*, 1920, 220; *Serratia rubrica* Bergey et al., Manual, 1st ed., 1923, 313; *Chromobacterium rubricum* Topley and Wilson, Princ. Bact. and Immun., *1*, 1931, 402.)

Rods: 0.7 to 0.9 by 1.0 to 4.0 microns, occurring singly. Non-motile. Gram reaction not given.

Gelatin colonies: Small, circular, yellow-orange, deepening to red.

Gelatin stab: Slow liquefaction. Old cultures lose this property.

Agar colonies: Circular, raised, entire.

Agar slant: Moist, spreading, white to pink, gradually deepening in color.

Broth: Turbid, with viscid sediment.

Litmus milk: Alkaline.

Potato: Slight growth, bright pink, turning coral red.

Indole not produced.

Nitrites not produced from nitrates.

No acid or gas from carbohydrate media.

Aerobic, facultative.

Optimum temperature 25° to 30°C. No growth at 37°C.

Source: Isolated from Mississippi river water, also from buttermilk.

3. **Bacillus rufus** Hefferan. (Hefferan, Cent. f. Bakt., II Abt., *11*, 1903, 313; *Erythrobacillus rufus* Holland, Jour. Bact., *5*, 1920, 220; *Serratia rufa* Bergey et al., Manual, 1st ed., 1923, 95.) From Latin *rufus*, red.

Differs from *Bacillus rubricus* in showing more luxuriant growth on potato and slower action in milk.

Source: From Mississippi River water.

4. **Bacillus mycoides corallinus** Hefferan. (Hefferan, Cent. f. Bakt., II Abt., *11*, 1903, 459; *Serratia corallina* Bergey et al., Manual, 1st ed., 1923, 93.)

Small, slender rods: 1.2 to 2.0 microns in length, occurring singly and in pairs. Non-motile. Gram reaction not given.

Gelatin colonies: Minute, becoming pink, smooth, raised.

Gelatin stab: Slow growth. Raised, smooth, glistening, pink surface growth. Fine, feathery growth in stab. No liquefaction.

Agar colonies: Minute, with filamentous margin.

Agar slant: Smooth, moist, salmon pink.

Broth: Turbid, with pink flakes on surface.

Litmus milk: Alkaline, with red surface.

Potato: Like agar slant.

Indole not formed.

Nitrites produced from nitrates.

No gas from carbohydrate media.

Aerobic, facultative.

Optimum temperature 25° to 30°C.

Source: Isolated from Mississippi river water.

5. **Bacillus bruntzii** Nepveux. (Nepveux, Compt. rend. Soc. Biol., Paris, *72*, 1920, 242; Thèse, Fac. de Pharm., Jouve et Cie, Paris, 1920, 136 pp.; *Serratia bruntzii* Bergey et al., Manual,

3rd ed., 1930, 125.) Named for Prof. Bruntz of Paris.

Bacillus roseus fluorescens Marchal (Trav. Lab. Microbiol. Fac. Pharm. Nancy, 1937, 90) is regarded by Lasseur (personal communication, 1938) as identical with *Bacillus bruntzii* Nepveux.

Rods: 0.3 to 0.5 by 1.25 to 1.5 microns, occurring singly and in pairs. Non-motile. Gram-negative. The cells store volutin and glycogen as reserve materials.

Gelatin colonies: Circular, gray, smooth, contoured, glistening, undulate margin, becoming red.

Gelatin stab: No liquefaction.

Agar colonies: Circular, flat, smooth, contoured, radiate margin, vinous red.

Agar slant: Smooth, echinulate, butyrous, vinous red in color.

Broth: Turbid.

Litmus milk: Unchanged.

Indole not formed.

Nitrites produced from nitrates.

Acid from glucose, fructose, maltose, lactose, sucrose, mannitol, dulcitol and glycerol.

Aerobic, facultative.

Optimum temperature 20° to 25°C.

Habitat: Water.

6. **Bacillus aurantiacus tingitanus** Remlinger and Bailly. (Compt. rend. Soc. Biol. Paris, *119*, 1935, 246.)

Short rods: Usually 2 to 3 microns, sometimes 5 to 6 microns long. Actively motile. Gram-negative.

Growth occurs on all the ordinary nutrient media. Fluorescent bright orange pigment.

Gelatin: Rapid liquefaction.

Milk: Slow coagulation.

Synthetic broth: Lasseur, Dupaix-Lasseur and Marion (Trav. Lab. Microbiol. Fac. Pharm. Nancy, Fasc. 9, 1936, 34) recognize two rough types of this organism, one of which forms a smooth and the other a wrinkled pellicle. The smooth type gives a rough (pH 4.7) or a smooth (pH 6.3) pellicle according to the pH of the medium.

Indole not formed.

Artichoke media: Luxuriant growth. Emerald green pigment produced. On transferring the culture to potato, the bright orange pigment reappears.

Coagulated serum: No liquefaction.

Acid from sucrose, lactose, glucose, mannitol and maltose.

Non-pathogenic.

Optimum pH 6.6. No growth at pH 6.2, but grows at pH 7.8.

Optimum temperature 20°C. Good growth from 15° to 37°C.

Aerobic.

Pigment: Orange or capucine pigment which diffuses throughout the medium. Not affected by the presence or absence of light. Pigment production depends on the growth of the culture, not on the acidity of the medium. Insoluble in acetone, amyl alcohol and gasoline. Partially soluble in ether and ethyl alcohol which are colored yellow.

Distinctive character: A fluorescent pigment of an unusual shade (bright orange).

Source: From water at Tangiers.

Habitat: Presumably water.

Appendix II:* The anaerobic genus *Methanobacterium* was proposed tentatively by Kluyver and Van Niel in 1936 with indication that they regarded Söhngen's methane bacterium as the type species of the genus. Later, Barker (1936) found organisms that he regarded as identical with those previously isolated by Söhngen and he proposed the name *Methanobacterium söhngenii* for this species. A second species found at the same time was named *Methanobacterium omelianskii* and it was identified as the species previously described but not named by Omeliansky. At the time, he felt that these anaerobes should be included in the family *Mycobacteriaceae* (1936,

* The manuscript for this section has been reviewed by Dr. H. Albert Barker, University of California, Berkeley, California, February, 1945.

p. 422). In 1940, he discovered that the second species produced spores. In a personal communication (March 20, 1945) he suggests that further work is needed before the relationships of these organisms can be clarified.

Genus A. **Methanobacterium** *Kluyver and Van Niel.*

(Cent. f. Bakt., II Abt., *94*, 1936, 399.)

Straight or slightly bent rods, sometimes united in bundles or long chains. Usually non-motile. Endospores sometimes formed. Anaerobic. Chemo-heterotrophic or chemo-autotrophic oxidizing various organic or inorganic compounds and reducing carbon dioxide to methane. Gram-variable, usually negative.

The type species is *Methanobacterium soehngenii* Barker.

1. **Methanobacterium soehngenii** Barker. (Methane bacterium, Söhngen, Dissertation, Delft, 1906; Barker, Arch. f. Mikrobiol., *7*, 1936, 433.) Named for Prof. N. L. Söhngen who first studied this organism.

Rods: Straight to slightly bent, moderately long. Non-motile. Non-spore-forming. Gram-negative.

In liquid cultures cells are characteristically joined into long chains which often lie parallel to one another so as to form bundles.

Acetate and n-butyrate but not propionate are fermented with the production of methane and carbon dioxide.

Ethyl and n-butyl alcohols not fermented.

Obligate anaerobe.

Source: Enrichment cultures containing acetate or butyrate as the only organic compound. Four strains were isolated from acetate enrichment cultures. The cultures were highly purified but not strictly pure.

Habitat: Canal mud, sewage. Probably occurs widely in fresh water sediments where anaerobic conditions prevail.

2. **Methanobacterium omelianskii** Barker. (Bacille de la décomposition méthanique de l'alcohol ethylique, Omeliansky, Ann. Inst. Past., *30*, 1916, 80; Barker, Arch f. Mikrobiol., *7*, 1936, 436; also see Barker, Antonie van Leeuwenhoek, *6*, 1940, 201 and Jour. Biol. Chem., *137*, 1941, 153.) Named for Prof. W. Omeliansky who first observed the organism.

Rods: 0.6 to 0.7 by 1.5 to 10 microns, usual length 3 to 6 microns, unbranched, straight or slightly bent. Usually non-motile, occasionally feeble motility is observed. Spores of low heat resistance formed, spherical, terminal, swelling the rods.

Primary alcohols, including ethyl, propyl, n-butyl and n-amyl alcohols, are oxidized to the corresponding fatty acids. Secondary alcohols, including isopropyl and sec-butyl, are oxidized to the corresponding ketones. Hydrogen is oxidized.

Fatty and hydroxy acids, glucose, polyalcohols and amino acids are not attacked.

Carbon dioxide is used and converted to methane. Growth and alcohol oxidation are directly proportional to the carbon dioxide supply at low concentrations.

Nitrate, sulfate and oxygen cannot be used as oxidizing agents.

Utilizes ethyl alcohol best of all organic compounds.

Utilizes ammonia as a nitrogen source.

Growing range: pH 6.5 to 8.1.

Optimum temperature 37° to 40°C. Maximum 46° to 48°C.

Obligate anaerobe.

Source: Soil, fresh water and marine muds, rabbit feces, sewage. Pure cultures were isolated from fresh water and marine muds (Barker, *loc. cit.*, 1940).

Habitat: Wherever organic matter is decomposing in an anaerobic, approximately neutral environment.

Appendix III: Miscellaneous species of non-motile, or motile, non-spore-forming rod-shaped bacteria not previously listed or described.

Ascobacterium luteum Babes. (Babes, in Cornil and Babes, Les Bactéries, 3rd ed., *1*, 1890, 155; also see Petri, Cent. f. Bakt., II Abt., *26*, 1910, 359.) From water in Budapest (Babes) and the olive fly (Petri).

Bacillus a, b, c, d, e, f, h and *i*, Vignal. (Arch. d. phys. norm. et path., Sér. 3, *8*, 1886, 350–373; also see *Flavobacterium buccalis* Bergey et al. and *Bacillus buccalis fortuitus* Sternberg.) From saliva and the teeth.

Bacillus acido-aromaticus Van der Leck. (Cent. f. Bakt., II Abt., *17*, 1907, 652.) From milk.

Bacillus acutangulus Migula. (No. 13, Lembke, Arch. f. Hyg., *29*, 1897, 319; Migula, Syst. d. Bakt., *2*, 1900, 680.) From feces.

Bacillus acutus Kern. (Arb. bakt. Inst. Karlsruhe, *1*, Heft 4, 1896, 433.) From the stomach of a bird.

Bacillus adametzii Migula. (Bacillus No. XIII, Adametz, Landwirtsch. Jahrb., *18*, 1889, 246; Migula, Syst. d. Bakt., *2*, 1900, 686; not *Bacillus adametzi* Trevisan, I generi e le specie delle Batteriacee, 1889, 19.) From cheese.

Bacillus aeris Chester. (*Bacillus violaceus sacchari* Ager, N. Y. Med. Jour., 1894, 265; see Dyar, Ann. N. Y. Acad. Sci., *8*, 1895, 369; *Bacterium violaceous sacchari* Chester, Ann. Rept. Del. Col. Agr. Exp. Sta., *9*, 1897, 116; Chester, Man. Determ. Bact., 1901, 260.) From air. Produces a violaceus black pigment in old cultures in milk.

Bacillus aerobius Doyen. (*Bacillus urinae aerobius* Doyen, Jour. d. connaiss. médic., 1889, 107; Doyen, *ibid.*, 108.) From urine.

Bacillus aerogenes Miller. (Miller, Deutsche med. Wchnschr., *12*, 1886, 119; see Miller, Die Mikroorganismen der Mundhöhle, Leipzig, 1889, 262; not *Bacillus aerogenes* Kruse, in Flügge, Die Mikroorganismen, 3 Aufl., *2*, 1896, 340.) From the stomach.

Bacillus aërogenes sputigenus capsulatus Herla. (Arch. de Biol., *14*, 1895, 403; abst. in Cent. f. Bakt., *25*, 1899, 359.) From the blood of a mouse which had been inoculated with the sputum of a pneumonia patient.

Bacillus aeschynomenus Trevisan. (Bacille de l'air *j*, Babes, in Cornil and Babes, Les Bactéries, 2nd ed., 1886, 150; Trevisan, I generi e le specie delle Batteriacee, 1889, 20.) From air.

Bacillus aëthebius Trevisan. (Bacille de l'air *c*, Babes, in Cornil and Babes, Les Bactéries, 2nd ed., 1886, 149; Trevisan, I generi e le specie delle Batteriacee, 1889, 20.) From air.

Bacillus agilis Trevisan. (Bacillus der Vagus-Pneumonie, Schou, Fortschr. d. Medicin, *3*, 1885, No. 15; *Bacillus pneumonicus agilis* Flügge, Die Mikroorganismen, 2 Aufl., 1886, 262; Trevisan, I generi e le specie delle Batteriacee, 1889, 14; not *Bacillus agilis* Tschistowitsch, Berl. klin. Wochnschr., 1892, 512; not *Bacillus agilis* Chester, Man. Determ. Bact., 1901, 226; not *Bacillus agilis* Mattes, Sitzungsber. d. Gesells. z. Beforderung d. gesam. Naturw. z. Marburg, *62*, 1927, 406; not *Bacillus agilis* Hauduroy et al., Dict. d. Bact. Path., Paris, 1937, 33; *Bacterium pneumonicus agilis* Chester, Ann. Rept. Del. Col. Agr. Exp. Sta., *9*, 1897, 140; *Bacterium vagus pneumonie* Chester, *ibid.*, 144; *Bacillus pneumonicus* Migula, Syst. d. Bakt., *2*, 1900, 752.) From the lungs of rabbits having vagus pneumonia.

Bacillus agilis Mattes. (Sitzungsber. d. Gesells. z. Beforderung d. gesam. Naturw. z. Marburg, *62*, 1927, 406.) From the Mediterranean flour moth (*Ephestia kuehniella*).

Bacillus agillimus DeToni and Trevisan. (*Bacillus luteus putidus* Maggiora, Giorn. d. Soc. ital. d'Igiene, *11*, 1889, 344; DeToni and Trevisan, in Saccardo, Sylloge Fungorum, *8*, 1889, 969.) From the skin.

Bacillus agnorum Trevisan. (*Bacterium subtile agnorum* Rivolta, Giorn. di Anat. fisiol. degli animali, 1881, 31 and 1883, 78; Trevisan, I generi e le specie delle Batteriacee, 1889, 13.) From diseased lambs.

Bacillus alacer Eckstein. (Ztschr. f. Forst- u. Jagdwesen, *26*, 1894, 13.) Found associated with the eggs of the nun moth (*Lymantria monacha*).

Bacillus alatus Grieg Smith. (Proc. Linn. Soc. New So. Wales, *30*, 1905, 570.)

Bacillus albatus Kern. (Arb. bakt. Inst. Karlsruhe, *1*, Heft 4, 1896, 408.) From the stomach and intestines of a bird.

Bacillus albus Pagliani, Maggiora and Fratini. (Weisser Bacillus, Eisenberg, Bakt. Diag., 1 Aufl., 1886, Table 7; Pagliani et al., Giorn. d. Soc. ital. d'Igiene, *9*, 1887, 587; not *Bacillus albus* Trevisan, I generi e le specie delle Batteriacee, 1889, 14; not *Bacillus albus* Bergey et al., Manual, 3rd ed., 1930, 398; *Bacterium albus* Chester, Ann. Rept. Del. Col. Agr. Exp. Sta., *9*, 1897, 76.) From water.

Bacillus albus anaerobiescens Vaughan. (Amer. Jour. Med. Sci., *104*, 1892, 191.) From water.

Bacillus albus putidus DeBary. (Quoted from Sternberg, Man. of Bact., 1893, 675.) From water.

Bacillus albus-putidus Chester. (Maschek, see Adametz, Bakt. Nutz. u. Trinkwässer, 1888; Chester, Man. Determ. Bact., 1901, 237.) From water.

Bacillus albus putridus Vaughan. (Amer. Jour. Med. Sci., *104*, 1892, 186.) From water.

Bacillus alpha Dyar. (Ann. N. Y. Acad. Sci., *8*, 1895, 366.) From air.

Bacillus amabilis Dyar. (Dyar, Ann. N. Y. Acad. Sci., *8*, 1895, 358; *Bacterium amabilis* Chester, Ann. Rept. Del. Col. Agr. Exp. Sta., *9*, 1897, 110.) From air.

Bacillus amarillae Trevisan. (Bacille de la fiévre jaune, Babes, in Cornil and Babes, Les Bactéries, 2nd ed., 1886, 529; Trevisan, I generi e le specie delle Batteriacee, 1889, 13.) From a case of yellow fever.

Bacillus amarus Migula. (*Bacillus liquefaciens lactis amari* v. Freudenreich, Landwirtsch. Jahrb. d. Schweiz, *8*, 1894; Migula, Syst. d. Bakt., *2*, 1900, 694; not *Bacillus amarus* Hammer, Iowa Agr. Exp. Sta. Res. Bull. 52, 1919, 198.) From bitter milk.

Bacillus amerimnus Trevisan. (Bacille de l'air *b*, Babes, in Cornil and Babes, Les Bactéries, 2nd ed., 1886, 149; Trevisan, I generi e le specie delle Batteriacee, 1889, 20.) From air.

Bacillus amygdaloides Weiss. (Arb. bakt. Inst. Karlsruhe, *2*, Heft 3, 1902, 246.) From brine on salted pickles.

Bacillus anceps Trevisan. (Bacille du mucus intestinal normal *a*, Babes, in Cornil and Babes, Les Bactéries, 2nd ed., 1886, 153; Trevisan, I generi e le specie delle Batteriacee, 1889, 15.) From normal intestinal mucous.

Bacillus anthraciformis Wilhelmy. (Arb. bakt. Inst. Karlsruhe, *3*, 1903, 28.) From meat extract.

Bacillus anthracoides Trevisan. (Bacille de l'air *k*, Babes, in Cornil and Babes, Les Bactéries, 2nd ed., 1886, 151; Trevisan, I generi e le specie delle Batteriacee, 1889, 20; not *Bacillus anthracoides* Kruse, in Flügge, Die Mikroorganismen, 3 Aufl., *2*, 1896, 232.) From air.

Bacillus annulatus Zimmermann. (Bakt. unserer Trink- u. Nutzwässer, Chemnitz, *2*, 1894, 30.) From water.

Bacillus anularius Henrici. (Arb. bakt. Inst. Karlsruhe, *1*, Heft 1, 1894, 32.) From Emmenthal cheese.

Bacillus apicum Kruse. (Canestrini, Atti Soc. Ven. Trent. Sci. Nat., *12*, 1892, 134; Kruse, in Flügge, Die Mikroorganismen, 3 Aufl., *2*, 1896, 233.) From infected bees and their larvae.

Bacillus apisepticus Burnside. (Jour. Econ. Ent., *21*, 1928, 379.) Pathogenic for the honey bee (*Apis mellifera*).

Bacillus aquatilis Migula. (*Bacillus*

aquatilis sulcatus IV, Weichselbaum, Das österreichische Sanitätswesen, 1889, No. 14–23; *Bacterium aquatilis sulcatus quartus* Chester, Ann. Rept. Del. Col. Agr. Exp. Sta., *9*, 1897, 72; Migula, Syst. d. Bakt., *2*, 1900, 733; not *Bacillus aquatilis* Frankland and Frankland, Ztschr. f. Hyg., *6*, 1889, 381; *Bacillus aquatilis-sulcatus-quartus* Chester, Man. Determ. Bact., 1901, 216.) From water.

Bacillus aquatilis Trevisan. (Bacille de l'eau *a*, Babes, in Cornil and Babes, Les Bactéries, 2nd ed., 1886, 167; Trevisan, I generi e le specie delle Batteriacee, 1889, 19; not *Bacillus aquatilis* Frankland and Frankland, Ztschr. f. Hyg., *6*, 1889, 381.) From water.

Bacillus aquatilis communis Kruse. (Kruse, in Flügge, Die Mikroorganismen, 3 Aufl., *2*, 1896, 315; *Bacterium aquatilis communis* Chester, Ann. Rept. Del. Col. Agr. Exp. Sta., *9*, 1897, 91.) Found commonly in water. Listed by Kruse as a non-chromogenic strain of *Bacillus fluorescens liquefaciens* (*Pseudomonas fluorescens* Migula).

Bacillus arborescens Jamieson and Edington. (Brit. Med. Jour., *1*, 1887, 1265.) From the desquamation of scarlet fever patients.

Bacillus arboreus Migula. (Bäumchenbacillus, Maschek, Bakt. Untersuch. d. Leitmeritzer Trinkwässer, Leitmeritz, 1887; Migula, Syst. d. Bakt., *2*, 1900, 710.) From water.

Bacillus aromaticus Beijerinck. (Quoted from Van der Leck, Cent. f. Bakt., II Abt., *17*, 1907, 490; not *Bacillus aromaticus* Pammel, Bull. 20, Iowa Agr. Exp. Sta., 1893, 792; not *Bacillus aromaticus* Grimm, Cent. f. Bakt., II Abt., *8*, 1902, 589; not *Bacillus aromaticus* Van der Leck, *loc. cit.*, 659.) From milk.

Bacillus aromaticus Van der Leck. (Van der Leck, Cent. f. Bakt., II Abt., *17*, 1907, 659.) From soft cheeses.

Bacillus assimilis Trevisan. (Bacille de l'air *i*, Babes, in Cornil and Babes, Les Bactéries, 2nd ed., 1886, 150; Trevisan, I generi e le specie delle Batteriacee, 1899, 20.) From air.

Bacillus aurantius Trevisan. (Orangerother Wasserbacillus, Adametz and Wichmann, Mitth. Oest. Vers. Stat. f. Brauerei u. Mälz. in Wien, *1*, 1888, 50; Trevisan, I generi e le specie delle Batteriacee, 1889, 19; not *Bacillus aurantius* Bergey et al., Manual, 3rd ed., 1930, 421.) From water.

Bacillus aureus Eckstein. (Ztschr. f. Forst- u. Jagdwesen, *26*, 1894, 9; probably not *Bacillus aureus* Frankland and Frankland, Philos. Trans. Roy. Soc. London, *178*, B, 1887, 272 and probably not *Bacillus aureus* Pansini, Arch. f. path. Anat. u. Physiol., *122*, 1890, 436; not *Bacillus aureus* Adametz, quoted from Sternberg, Man. of Bact., 1893, 621.) Capable of infecting the larvae of various insects.

Bacillus azureus Zimmermann. (Bakt. unserer Trink- u. Nutzwässer, Chemnitz, *2*, 1894, 24.) From water.

Bacillus babesi Trevisan. (Bacille du mucus intestinal normal *b*, Babes, in Cornil and Babes, Les Bactéries, 2nd ed., 1886, 153; Trevisan, I generi e le specie delle Batteriacee, 1889, 15.) From normal intestinal mucus.

Bacillus belfantii Migula. (Eine neue pathogene Bakteriumart im Tetanusmaterial, Belfanti and Pescarolo, Cent. f. Bakt., *4*, 1888, 513; *Bacillus accidentalis tetani* Kruse, in Flügge, Die Mikroorganismen, 3 Aufl., *2*, 1896, 433; *Bacterium accidentalis tetani* Chester, Ann. Rept. Del. Col. Agr. Exp. Sta., *9*, 1897, 88; Migula, Syst. d. Bakt., *2*, 1900, 767; not *Bacillus belfanti* Carbone and Venturelli, Boll. Ist. Sieroter., Milan, *4*, 1925, 59; *Bacillus accidentalis* Chester, Man. Determ. Bact., 1901, 229.) From pus in a case of tetanus.

Bacillus benzoli Tausson. (Planta, *7*, 1929, 735.) From soil. Oxidizes benzene.

Bacillus beribericus Trevisan. (Caratt. di alc. nuov. gen. di Batt., 1885, 12.) From cases of beri-beri in Japan.

Also see Ogata, abst. in Cent. f. Bakt., *3*, 1888, 75.

Bacillus berolinensis Migula. (Roter Bacillus aus Wasser, Fraenkel, Grundriss der Bakterienkunde, 3 Aufl., 1890, 252; *Bacillus ruber berolinensis* Kruse, in Flügge, Die Mikroorganismen, 3 Aufl., *2*, 1896, 303; *Bacterium ruber berolinensis* Chester, Ann. Rept. Del. Col. Agr. Exp. Sta., *9*, 1897, 113; Migula, Syst. d. Bakt., *2*, 1900, 856; not *Bacillus berolinensis* Chester, Man. Determ. Bact., 1901, 305.) From water. Rust-red to orange-yellow pigment on potato.

Bacillus beta Dyar. (Ann. N. Y. Acad. Sci., *8*, 1895, 366.) From air.

Bacillus beyerinckii DeToni and Trevisan. (*Bacillus radicicola* var. *liquefaciens* Beijerinck, Bot. Zeitung, 1888, 750; DeToni and Trevisan, in Saccardo, Sylloge Fungorum, *8*, 1889, 972; not *Bacillus beijerinckii* Henneberg, Ztschr. f. Spiritusindustrie, *26*, 1903, 22; see Cent. f. Bakt., II Abt., *11*, 1903, 159.) From soil and the roots of legumes.

Bacillus billingsi Chester. (Bacillus of corn-stalk disease of cattle, Billings, in Baumgarten, Jahresbericht, 1889, 184; Chester, Man. Determ. Bact., 1901, 214.) Isolated by Billings from corn-stalk disease of cattle, and by Nocard from bronchopneumonia in oxen.

Bacillus bombycis Chatton. (Chatton, Compt. rend. Acad. Sci., Paris, *156*, 1913, 1708; not *Bacillus bombycis* Macchiati, Stazioni sperimentali Agrarie Italiane, *20*, 1891, 121; *Bacterium bombycis* Paillot, L'infection chez les insectes, 1933, 131.) From diseased silkworms (*Bombyx mori*).

Bacillus bookeri Dyar. (Dyar, Ann. N. Y. Acad. Sci., *8*, 1895, 378; not *Bacillus bookeri* Ford, Studies from the Royal Victoria Hospital, Montreal, *1*, 1903, 31.) Found by Dr. Prudden in a case of cystitis.

Bacillus brachythrix DeToni and Trevisan. (*Bacillus G*, Maggiora, Giorn. Soc. ital. d'Igiene, *11*, 1889, 348; DeToni and Trevisan, in Saccardo, Sylloge Fungorum, *8*, 1889, 967.) From the skin.

Bacillus brunneus (Schroeter) Schroeter. (*Bacteridium brunneum* Schroeter, in Cohn, Beitr. z. Biol. d. Pflanz., *1*, Heft 2, 1872, 126; Schroeter, in Cohn, Kryptog. Flora v. Schlesien, *3* (1), 1886, 158; not *Bacillus brunneus* Adametz and Wichmann, Die Bakt. der Nutz- und Trinkwässer, Wien, 1888; *Bacillus fuscus* Flügge, Die Mikroorganismen, 2 Aufl., 1886, 290; not *Bacillus fuscus* Zimmermann, Bakt. unserer Trink- u. Nutzwässer, Chemnitz, *1*, 1890, 70.) *Bacterium brunneum* Schroeter or Cohn is given as a synonym by Flügge (1886) and by Trevisan (1889) but this appears to be an incorrect spelling of *Bacteridium brunneum* Schroeter. Neither Schroeter nor Cohn used *Bacterium brunneum* in 1872 or later so far as can be determined by a careful study of their papers. From corn, wheat and potato infusions.

Bacillus buccalis fortuitus Sternberg. (Bacillus j, Vignal, Arch. Phys. norm. et path., Sér. 3, *8*, 1886, 337; Sternberg, Man. of Bact., 1893, 685; *Bacterium bucalis* (sic) *fortuitus* Chester, Ann. Rept. Del. Col. Agr. Exp. Sta., *9*, 1897, 91 and 130; *Bacillus bucalis* (sic) Chester, Man. Determ. Bact., 1901, 234; not *Bacillus buccalis* Trevisan, I generi e le specie delle Batteriacee, 1889, 15.) From the mouth.

Bacillus buccalis muciferens Miller. (Miller, Dental Cosmos, *33*, 1891, 792 and 800.) From the blood. A slimy capsulated bacillus.

Bacillus buccalis septicus Miller. (Miller, Dental Cosmos, *33*, 1891, 792 and 802.) From the mouth and in pus of an abscess caused by a dental instrument.

Bacillus butyri Migula. (*Bacillus butyri I*, v. Klecki, Cent. f. Bakt., *15*, 1894, 357; Migula, Syst. d. Bakt., *2*, 1900, v and 811.) From rancid butter.

Bacillus caeci Ford. (Studies from the Royal Victoria Hosp., Montreal, *1*, (5), 1903, 45; also see Jour. Med. Res.,

1, 1901, 217.) From the stomach and rectum.

Bacillus canalensis Castellani. (Proc. Soc. Exp. Biol. and Med., *25*, 1928, 540.) From human feces.

Bacillus canus Migula. (Grauer Bacillus, Maschek, Untersuch. d. Leitmeritzer Trinkwässer, Leitmeritz, 1887; Migula, Syst. d. Bakt., *2*, 1900, 711.) From water.

Bacillus canus Eckstein. (Ztschr. f. Forst- u. Jagdwesen, *24*, 1894, 15.) From larvae of the nun moth (*Lymantria monacha*.)

Bacillus carabiformis Raczyscki. (Diss. milit. medic. Acad. Petropolitanae Ruteniae, 1888; abst. in Cent. f. Bakt., *6*, 1889, 113.) From the stomach of a dog.

Bacillus carnis Wilhelmy. (Wilhelmy, Arb. bakt. Inst. Karlsruhe, *3*, 1903, 21; not *Bacillus carnis* Klein, Cent. f. Bakt., II Abt., *35*, 1903, 459.) From meat extract.

Bacillus caseolyticus Lochmann. (Cent. f. Bakt., I Abt., Orig., *31*, 1902, 385.) From the organs of guinea pigs which had been inoculated with tubercle bacilli.

Bacillus cathetus Trevisan. (Bacille de l'air *g*, Babes, in Cornil and Babes, Les Bactéries, 2nd ed., 1886, 150; Trevisan, I generi e le specie delle Batteriacee, 1889, 20.) From air.

Bacillus caviae Trevisan. (Bacille du mucus intestinal normal du cobaye *e*, Babes, in Cornil and Babes, Les Bactéries, 2nd ed., 1886, 154; Trevisan, I generi e le specie delle Batteriacee, 1889, 15; *Pasteurella caviae* DeToni and Trevisan, in Saccardo, Sylloge Fungorum, *8*, 1889, 996; not *Pasteurella caviae* Hauduroy et al., Dict. d. Bact. Path., 1937, 313.) From the intestinal mucus of guinea pigs.

Bacillus centralis Zimmermann. (Bakt. unserer Trink. u. Nutzwässer, Chemnitz, *2*, 1894, 10.) From water.

Bacillus charrini Trevisan. (Bacille de la pseudo-tuberculose bacillaire du cobaye, Charrin and Roger, Compt. rend. Acad. Sci., Paris, *106*, 1888, 868; Trevisan, I generi e le specie delle Batteriacee, 1889, 13.) From pulmonary tuberculosis of guinea pigs.

Bacillus chlorinus Migula. (Grüngelber Bacillus, Tataroff, Inaug. Diss., Dorpat, 1891, 50; Migula, Syst. d. Bakt., *2*, 1900, 820; not *Bacillus chlorinus* Frankland and Frankland, Philos. Trans. Roy. Soc. London, *178*, B, 1887, 274.) From water.

Bacillus chyluriae Trevisan. (Bacillus of chyluria, Wilson, Brit. Med. Jour., No. 1249, 1884, 1128; Trevisan, Atti Acad. Med.-Fis.-Stat. Milan., Ser. V, *3*, 1885, 99.) From chyluria.

Bacillus citreus (Unna and Tommasoli) Kruse. (*Ascobacillus citreus* Unna and Tommasoli, Monats. f. prakt. Dermatol., *9*, 1890, 60; Kruse, in Flügge, Die Mikroorganismen, 3 Aufl., *2*, 1896, 309; not *Bacillus citreus* Frankland and Frankland, Philos. Trans. Roy. Soc., London, *178*, 1887, B, 272; *Bacterium citreus* Chester, Ann. Rept. Del. Col. Agr. Exp. Sta., *9*, 1897, 104.) From the human skin in cases of eczema.

Bacillus citricus Kern. (Kern, Arb. bakt. Inst. Karlsruhe, *1*, Heft 4, 1896, 426; not *Bacillus citricus* Weiss, *ibid.*, *2*, Heft 2, 1902, 234.) From the intestines of birds.

Bacillus citrinus Migula. (Citrongelber Bacillus, Maschek, Bakt. Untersuch. d. Leitmeritzer Trinkwässer, 1887; Migula, Syst. d. Bakt., *2*, 1900, 832.) From water.

Bacillus cladogenes Trevisan. (Bactérie de l'air No. 3, Babes, in Cornil and Babes, Les Bactéries, 2nd ed., 1886, 140; Trevisan, I generi e le specie delle Batteriacee, 1889, 20.) From air.

Bacillus claviformis Doyen. (*Bacillus urinae claviformis* Doyen, Jour. d. connaiss. médic., 1889, 106; Doyen, *ibid.*, 108; *Bacillus doyeni* DeToni and Trevi-

san, in Saccardo, Sylloge Fungorum, *8*, 1889, 949.) From urine.

Bacillus cleoni Picard. (Bull. Soc. d'Étude et de Vulgarisation Zool. Agric., *12*, 1913, 134.) A fluorescent coccobacillus. From diseased larvae of weevils (*Temnorrhinus* (*Cleonus*) *mendicus*).

Bacillus coccineus Catiano. (Catiano, in Cohn, Beitr. z. Biol. d. Pflanz., *7*, 1896, 339; not *Bacillus coccineus* Pansini, Arch. f. path. Anat., *122*, 1890, 437; *Bacillus subcoccineus* Migula, Syst. d. Bakt., *2*, 1900, 857.) From the vagina. Reddish pigment.

Bacillus coeruleo-viridis Trevisan. (Blaugrün fluorescirende Bacterium, Adametz, Mitth. Oest. Vers. Stat. f. Brauerei u. Mälz. in Wien, *1*, 1888, 46; Trevisan, I generi e le specie delle Batteriacee, 1889, 20; *Bacterium coeruleoviride* DeToni and Trevisan, in Saccardo, Sylloge Fungorum, *8*, 1889, 1087.) From water.

Bacillus coeruleus Eckstein. (Eckstein, Ztschr. f. Forst- u. Jagdwesen, *26*, 1894, 14; not *Bacillus coeruleus* Smith, Med. News, 1887, 758; probably not *Bacillus coeruleus* Voges, Cent. f. Bakt., *14*, 1893, 301.) From larvae of the nun moth (*Lymantria monacha*).

Bacillus columbarum Chester. (Bacillus of pigeon cholera, Moore, U.S. D.A., Bur. Anim. Ind., Bull. 8, 1895; Chester, Man. Determ. Bact., 1901, 209.) From a disease of pigeons. Hadley et al. (Rhode Island Agr. Exp. Sta., Bull. 174, 1918, 178) regard this as probably a paracolon.

Bacillus constrictus Zimmermann. (Zimmermann, Bakt. unserer Trink- u. Nutzwässer, Chemnitz, *1*, 1890, 42; *Bacterium constrictus* Chester, Ann. Rept. Del. Col. Agr. Exp. Sta., *9*, 1897, 112.) From water.

Bacillus convolutus Wright. (Wright, Mem. Nat. Acad. Sci., *7*, 1895, 461; *Bacterium convolutus* Chester, Ann. Rept. Del. Col. Agr. Exp. Sta., *9*, 1897, 101.) From river water.

Bacillus coprogenes foetidus Sternberg. (Darmbacillus, Schottelius, 1885; Sternberg, Man. of Bact., 1893, 468.) From the intestinal contents of pigs which had died of swine erysipelas.

Bacillus coronatus Keck. (Inaug. Diss., Dorpat, 1890, 43.) From water.

Bacillus corvi Kern. (Arb. bakt. Inst. Karlsruhe, *1*, Heft 4, 1896, 394.) From the stomach and intestines of birds.

Bacillus courmontii Migula. (Courmont, Compt. rend. Soc. Biol., Paris, 1889; *Bacillus pseudotuberculosis similis* Kruse, in Flügge, Die Mikroorganismen, 3 Aufl., *2*, 1896, 454; Migula, Syst. d. Bakt., *2*, 1900, 770.) From tubercles of cattle.

Bacillus crassus Lucet. (*Bacillus crassus pyogenes bovis* Lucet, Ann. Inst. Past., *7*, 1897, 327; *Bacillus crassus pyogenes* Lucet, *ibid.*, 327; Lucet, *ibid.*, 328; *Bacillus pyogenes crassus* Kruse, in Flügge, Die Mikroorganismen, 3 Aufl., *2*, 1896, 343; *Bacterium pyogenes crassus* Chester, Ann. Rept. Del. Col. Agr. Exp. Sta., *9*, 1897, 141; *Bacillus bovis* Migula, Syst. d. Bakt., *2*, 1900, 765.) From bovine abscesses. Regarded by Kruse as a synonym of *Bacillus pneumoniae*.

Bacillus crinitus Migula. (No. 15, Lembke, Arch. f. Hyg., *29*, 1897, 321; Migula, Syst. d. Bakt., *2*, 1900, 678.) From feces.

Bacillus cubonianus Cuboni and Garbini. (Atti. dei Lincei, Ser. 4, *6*, 1890, 26–27, quoted from Steinhaus, Bact. Assoc. Extracell. with Insects and Ticks, Minneapolis, 1942, 53; not *Bacillus cubonianus* Macchiati, Staz. Sperim. Agr. Ital., *23*, 1892, 228.) From silkworms (*Bombyx mori*).

Bacillus cuenoti Mercier. (Bakterienähnlichen Gebilden, Blochmann, Ztschr. f. Biol., *24*, 1887, 1; Compt. rend. Soc. Biol., Paris, *61*, 1906, 682; also in Arch. f. Protistenkunde, *9*, 1907, 346.) From the fat body of the cockroach (*Periplaneta orientalis*).

Bacillus cuniculi Migula. (*Bacillus septicus cuniculi* Lucet, Ann. Inst. Past., *6*, 1892, 564; *Bacillus cuniculi septicus* Kruse, in Flügge, Die Mikroorganismen,

3 Aufl., *2*, 1896, 406; *Bacterium cuniculi septicus* Chester, Ann. Rept. Del. Col. Agr. Exp. Sta., *9*, 1897, 76; Migula, Syst. d. Bakt., *2*, 1900, 758.) Associated with a spontaneous epizootic of rabbits.

Bacillus cuniculicida immobilis Kruse. (Kruse, in Flügge, Die Mikroorganismen, 3 Aufl., *2*, 1896, 417; *Bacterium cuniculicida immobilis* Chester, Ann. Rept. Del. Col. Agr. Exp. Sta., *9*, 1897, 84; *Bacterium cuniculicida* var. *immobile* Chester, Man. Determ. Bact., 1901, 140.) Cause of a disease of rabbits.

Bacillus cystiformis Clado. (Quoted from Sternberg, Man. of Bact., 1893, 649). From urine in a case of cystitis.

Bacillus cystitidis Migula. (*Coccobacillus aerogenes vesicae* Schow, Cent. f. Bakt., *12*, 1892, 749; *Bacillus aerogenes vesicae* Lehmann and Neumann, Bakt. Diag., 1 Aufl., *2*, 1896, 237; *Bacterium aerogenes vesicae* Chester, Ann. Rept. Del. Col. Agr. Exp. Sta., *9*, 1897, 128; Migula, Syst. d. Bakt., *2*, 1900, 771; *Bacillus aerogenes* Chester, Man. Determ. Bact., 1901, 227; not *Bacillus aerogenes* Miller, Deutsche med. Wochnschr., *12*, 1886, 119; not *Bacillus aerogenes* Kruse, in Flügge, Die Mikroorganismen, 3 Aufl., *2*, 1896, 340.) From urine in a case of cystitis.

Bacillus dacryoideus Migula. (*Bacillus oogenes hydrosulfureus* η, Zörkendörfer, Arch. f. Hyg., *16*, 1893, 389; Migula, Syst. d. Bakt., *2*, 1900, 791.) From hens' eggs.

Bacillus decolor Eckstein. (Ztschr. f. Forst- u. Jagdwesen, *26*, 1894, 15.) From the larvae of a butterfly (*Vanessa utricae*).

Bacillus decolorans major Dyar. (Ann. N. Y. Acad. Sci., *8*, 1895, 362.) From air.

Bacillus decolorans minor Dyar. (Ann. N. Y. Acad. Sci., *8*, 1895, 359.) From air.

Bacillus defessus Kern. (Arb. bakt. Inst. Karlsruhe, *1*, Heft 4, 1896, 397.) From the stomach and intestines of birds.

Bacillus delta Dyar. (Dyar, Ann. N. Y. Acad. Sci., *8*, 1895, 368; *Bacterium delta* Chester, Ann. Rept. Del. Col. Agr. Exp. Sta., *9*, 1897, 114.) From water.

Bacillus denitrificans Giltay and Aberson. (Giltay and Aberson, Arch. Néerl. Sci. exact. et nat., *25*, 1891, 341; quoted from Sternberg, Man. of Bact., 1893, 727; not *Bacillus denitrificans* Migula, Syst. d. Bakt., *2*, 1900, 796; not *Bacillus denitrificans* Chester, Man. Determ. Bact., 1901, 274.) From soil and air.

Bacillus denitrofluorescens van Iterson. (Cent. f. Bakt., II Abt., *9*, 1902, 772; *12*, 1904, 111.) Fluorescent. From soil.

Bacillus dentalis viridans Miller. (Miller, Die Mikroorganismen der Mundhöhle, Leipzig, 1889, 218.) From carious teeth.

Bacillus dermoides Tataroff. (Inaug. Diss., Dorpat, 1891, 19.) From water.

Bacillus diaphanus Migula. (*Halibacterium pellucidum* Fischer, Die Bakterien des Meeres, 1894, 22; Migula, Syst. d. Bakt., *2*, 1900, 712.) From sea water.

Bacillus diffluens Doyen. (*Bacillus urinae diffluens* Doyen, Jour. d. connaiss. médic., 1889, 107; Doyen, *ibid.*, 108; not *Bacillus diffluens* Castellani, 1915, see Castellani and Chalmers, Man. Trop. Med., 3rd ed., 1919, 943.) From urine.

Bacillus digitatus Migula. (Bacillus No. 7, Pansini, Arch. f. path. Anat., *122*, 1890, 443; Migula, Syst. d. Bakt., *2*, 1900, 659.) From sputum.

Bacillus dissimilis Trevisan. (Bacillus I, Leube, Arch. f. path. Anat., *100*, 1885, 556; Trevisan, I generi e le specie delle Batteriacee, 1889, 16.) From urine.

Bacillus domesticus Dyar. (Dyar, Ann. N. Y. Acad. Sci., *8*, 1895, 358; *Bacterium domesticus* Chester, Ann. Rept. Del. Col. Agr. Exp. Sta., *9*, 1897, 110.) From air.

Bacillus droserae (Troili-Petersson) Buchanan and Hammer. (*Bacterium droserae* Troili-Petersson, Cent. f. Bakt., II Abt., *38*, 1913, 1; Buchanan and Hammer, Iowa Sta. Coll. Agr. Exp. Sta., Res. Bull. 22, 1915, 256.) Isolated by placing leaves of a sundew (*Drosera intermedia*) in milk and isolating the

slimy milk organisms developing. Closely related to *Bacterium lacto-rubefaciens* Gruber, according to Buchanan and Hammer.

Bacillus duclauxii (Miquel) DeToni and Trevisan. (*Urobacillus duclauxii* Miquel, Ann. d. Microgr., *2*, 1889, 58; DeToni and Trevisan, in Saccardo, Sylloge Fungorum, *8*, 1889, 963.) From sewage.

Bacillus eczemicus Trevisan. (I generi e le specie delle Batteriacee, 1889, 14.) From exudate in cases of eczema.

Bacillus egregius Zopf. (Quoted from Papenhausen, Arb. bakt. Inst. Karlsruhe, *3*, 1903, 59.) A reddish-yellow non-spore-forming rod.

Bacillus elipsoideus Migula. (*Bacillus saprogenes vini* v, Kramer, Die Bakterien in ihren Beziehungen zur Landwirtschaft, *2*, 1892, 138; Migula, Syst. d. Bakt., *2*, 1900, 684.) From wine.

Bacillus ellingtonii Chester. (Bacillus No. 21, Conn, Rept. Conn. (Storrs) Agr. Exp. Sta., 1893, 52; Chester, Man. Determ. Bact., 1901, 264.) From milk.

Bacillus eminans Weiss. (Arb. bakt. Inst. Karlsruhe, *2*, Heft 3, 1902, 232.) From vegetable infusions.

Bacillus emulsinus Fermi and Montesano. (Cent. f. Bakt., *15*, 1894, 722.) From air. Decomposes amygdalin.

Bacillus endocarditidis Migula. (*Bacillus endocarditidis griseus* Weichselbaum, Beitr. z. path. Anat., *4*, 1889, 119; *Bacterium endocarditidis griseus* Chester, Ann. Rept. Del. Col. Agr. Exp. Sta., *9*, 1897, 88; Migula, Syst. d. Bakt., *2*, 1900, 750.) From a case of endocarditis.

Bacillus engelmanni Trevisan. (*Bacterium chlorinum* Engelmann, see Flügge, Die Mikroorganismen, 2 Aufl., 1886, 289; not *Bacterium chlorinum* Migula, Syst. d. Bakt., *2*, 1900, 471; Trevisan, I generi e le specie delle Batteriacee, 1889, 18.) Source not given.

Bacillus enteromyces Trevisan. (Bacille des selles *f*, Babes, in Cornil and Babes, Les Bactéries, 2nd ed., 1886, 154; Trevisan, I generi e le specie delle Batteriacee, 1889, 15.) From feces.

Bacillus entomotoxicon Duggar. (Bull. Illinois State Lab. Nat. Hist., *4*, 1896, 340–379.) From the squash bug (*Anasa tristis*).

Bacillus epsilon Dyar. (Dyar, Ann. N. Y. Acad. Sci., *8*, 1895, 369; *Bacterium epsilon* Chester, Ann. Rept. Del. Col. Agr. Exp. Sta., *9*, 1897, 114.) From air.

Bacillus equi Migula. (*Bacillus equi intestinalis* Dyar and Keith, Technol. Quarterly, *6*, 1893, No. 3; abst. in Cent. f. Bakt., *16*, 1894, 838; *Bacterium equi intestinalis* Chester, Ann. Rept. Del. Col. Agr. Exp. Sta., *9*, 1897, 70; Migula, Syst. d. Bakt., *2*, 1900, 874; *Bacillus intestinalis* Chester, Man. Determ. Bact., 1901, 213.) From the intestines of a horse.

Bacillus erubescens Migula. (*Bacillus oogenes hydrosulfureus* κ, Zörkendörfer, Arch. f. Hyg., *16*, 1893, 391; Migula, Syst. d. Bakt., *2*, 1900, 792; *Bacillus rubescens* Nepveux, Thèse, Fac. Pharm. Paris, 1920, 113.) From hens' eggs.

Bacillus erythrogenes rugatus Dyar. (Ann. N. Y. Acad. Sci., *8*, 1895, 374.) A wrinkled variety of *Bacillus lactis erythrogenes* Hueppe.

Bacillus erythrosporus Miflet. (Miflet, in Cohn, Beitr. z. Biol. d. Pflanz., *3*, Heft 1, 1879, 135; *Bacillus* (*Streptobacter*) *erythrospores* (sic) Schroeter, in Cohn, Krypt. Flora v. Schles., *3*, 1, 1886, 158; *Bacterium erythrosporus* Chester, Ann. Rept. Del. Col. Agr. Exp. Sta., *9*, 1897, 123.) From putrefying egg-white and meat infusion. According to Chester, the author mistook reddish granules for spores. Fluorescent.

Bacillus esterificans fluorescens Maassen. (Arb. a. d. k. Gesundsheitsamte, *15*, 1899, 504–507.) From grains and from rotting vegetation in river water.

Bacterium esterificans stralauense Maassen. (Arb. a. d. k. Gesundheitsamte, *15*, 1899, 504–507.) From Spree River water.

Bacillus eta Dyar. (Dyar, Ann. N. Y. Acad. Sci., *8*, 1895, 374; *Bacterium eta* Chester, Ann. Rept. Del. Col. Agr. Exp. Sta., *9*, 1897, 107.) From air.

Bacillus ethaceticus Frankland and

Frankland. (Proc. Roy. Soc. London, *46*, 1889.) Ferments mannitol, glycerol and glucose to ethyl alcohol and acetic acid with a trace of formic and succinic acids.

Bacillus ethacetosuccinicus Frankland and Frew. (Transactions of the Chemical Society, 1892, 275.) Ferments mannitol and dulcitol to ethyl alcohol, acetic acid, succinic acid, hydrogen and carbonic acid.

Bacillus exapatus Trevisan. (Bacillus der conjunctivalsack *f*, Fick, Ueber Mikroorg. in Conjunctivalsack, Wiesbaden, 1887; Trevisan, I generi e le specie delle Batteriacee, 1889, 15.) Found frequently in the human eye.

Bacillus exiguus Wright. (Wright, Mem. Nat. Acad. Sci., *7*, 1895, 447; *Bacterium exiguum* Chester, Ann. Rept. Del. Col. Agr. Exp. Sta., *9*, 1897, 114; not *Bacterium exiguum* Stäubli, Münchner med. Wochnschr., No. 45, 1905.) From water.

Bacillus famiger Trevisan. (Bacillus bei Erysipel am Kaninchenohr, Flügge, Die Mikroorganismen, 2 Aufl., 1886, 283; Trevisan, I generi e le specie delle Batteriacee, 1889, 14.) From a case of erysipelas of the ear of a rabbit.

Bacillus felis (Rivolta) Trevisan. (*Cocco-bacterium felis* Rivolta, Giorn. di Anatomia, No. 1, 1888; Trevisan, I generi e le specie delle Batteriacee, 1889, 14.) From an infection in a cat.

Bacillus fermentationis Chester. (*Bacillus foetidus liquefaciens* Tavel, Ueber d. Actiol. d. Strumitis, Basel, 1892; Chester, Man. Determ. Bact., 1901, 233.) From strumitis.

Bacillus ferrugineus Rullmann. (Rullmann, Cent. f. Bakt., I Abt., *24*, 1898, 467; not *Bacillus ferrugineus* Van Iterson, Cent. f. Bakt., II Abt., *11*, 1903, 694.) From canal water.

Bacillus ferrugineus Dyar. (Dyar, Ann. N. Y. Acad. Sci., *8*, 1895, 361; not *Bacillus ferrugineus* Rullmann, Cent. f. Bakt., I Abt., Orig., *24*, 1898, 465; *Bacterium furrugineus* (sic) Chester, Ann. Rept. Del. Col. Agr. Exp. Sta., *9*, 1897, 115; *Bacterium ferrugineum* Chester, Man. Determ. Bact., 1901, 177.) From air and from a fresh leaf of the pitcher plant (*Sarracenia purpurea*).

Bacillus fertilis DeToni and Trevisan. (*Bacillus urinae fertilis* Doyen, Jour. d. connaiss. médic., 1889, 107; DeToni and Trevisan, in Saccardo, Sylloge Fungorum, *8*, 1889, 949.) From urine.

Bacillus figurans Vaughan. (Vaughan, Amer. Jour. Med. Sci., *104*, 1892, 107; not *Bacillus figurans* Crookshank, Man. of Bact., 1st ed., 1886.) From water.

Bacillus finitimus ruber Dyar. (Ann. N. Y. Acad. Sci., *8*, 1895, 361.) From air.

Bacillus flavidescens Migula. (*Bacillus aquatilis sulcatus* v, Weichselbaum, Das österreichische Sanitätswesen, 1889, No. 14–23; *Bacillus aquatilis sulcatus* Kruse, in Flügge, Die Mikroorganismen, 3 Aufl., *2*, 1896, 382; Migula, Syst. d. Bakt., *2*, 1900, 734; *Bacillus weichselbaumii* Chester, Man. Determ. Bact., 1901, 218.) From water.

Bacillus flavoides Castellani. (Proc. Soc. Exp. Biol. and Med., *25*, 1928, 539.) From the human skin.

Bacillus flavus Eckstein. (Ztschr. f. Forst- u. Jagdwesen, *26*, 1894, 12; not *Bacillus flavus* Fuhrmann, Cent. f. Bakt., II Abt., *19*, 1907, 117; not *Bacillus flavus* Bergey et al., Manual, 1st ed., 1923, 286.) From dead larvae of a butterfly (*Vanessa polychlorus*).

Bacillus flexuosus Wright. (Wright, Mem. Nat. Acad. Sci., *7*, 1895, 460; *Bacterium flexuosus* Chester, Ann. Rept. Del. Col. Agr. Exp. Sta., *9*, 1897, 100.) From river water.

Bacillus floccosus Kern. (Kern, Arb. bakt. Inst. Karlsruhe, *1*, Heft 4, 1896, 424; not *Bacillus floccosus* Weinberg et al., Les Microbes Anaérobies, 1937, 698.) From the stomach and intestines of birds.

Bacillus fluidificans DeToni and Trevisan. (*Bacillus fluidificans parvus* Maggiora, Giorn. Soc. ital. d'Igiene, *11*, 1889, 344; DeToni and Trevisan, in Saccardo, Sylloge Fungorum, *8*, 1889, 969.) From the skin.

Bacillus fluorescens Chester. (*Bacillus fluorescens aureus* Zimmermann, Bakt. unserer Trink- u. Nutzwässer, Chemnitz, *1*, 1890, 14; *Bacterium fluorescens aureus* Chester, Ann. Rept. Del. Col. Agr. Exp. Sta., *9*, 1897, 109; Chester, Man. Determ. Bact., 1901, 255; not *Bacillus fluorescens* Trevisan, I generi e le specie delle Batteriacee, 1889, 19; not *Bacillus fluorescens* Bergey et al., Manual, 1st ed., 1923, 287.) From water.

Bacillus fluorescens Pagliani, Maggiora and Fratini. (Pagliani et al., Giorn. d. Soc. ital. d'Igiene, *9*, 1887, 587; not *Bacillus fluorescens* Bergey et al., Manual, 1st ed., 1923, 287; *Bacillus paglianii* Trevisan, I generi e le specie delle Batteriacee, 1889, 19; not *Bacillus paglianii* Carbone and Venturelli, Boll. Ist. Sieroter., Milan, *4*, 1925, 59.) From water and soil.

Bacillus fluorescens albus Zimmermann. (Bakt. unserer Trink- u. Nutzwässer, Chemnitz, *1*, 1890, 18.) From water.

Bacillus fluorescens baregensis Robine and Hauduroy. (Compt. rend. Soc. Biol. Paris, *98*, 1928, 25.) From the water of hot sulfur springs. Fourment (Compt. rend. Soc. Biol. Paris, *98*, 1928, 588) states that this organism is a variety of *Bacillus fluorescens liquefaciens* Kruse, but Robine and Hauduroy (Compt. rend. Soc. Biol. Paris, *99*, 1928, 317) deny this.

Bacillus fluorescens liquefaciens minutissimus Unna and Tommasoli. (Quoted from Sternberg, Man. of Bact., 1893, 636.) From the surface of the body in cases of eczema seborrhoeicum.

Bacillus fluorescens longus Zimmermann. (Zimmermann, Bakt. unserer Trink- u. Nutzwässer, Chemnitz, *1*, 1890, 20; *Bacterium fluorescens longus* Chester, Ann. Rept. Del. Col. Agr. Exp. Sta., *9*, 1897, 124.) From water.

Bacillus fluorescens tenuis Zimmermann. (Zimmermann, Bakt. unserer Trink- u. Nutzwässer, Chemnitz, *1*, 1890, 14; *Bacterium fluorescens tenuis* Chester, Ann. Rept. Del. Col. Agr. Exp. Sta., *9*, 1897, 124.) From water.

Bacillus foetidus Eckstein. (Ztschr. f. Forst- u. Jagdwesen, *26*, 1894, 12.) From dead larvae of a butterfly (*Vanessa urticae*).

Bacillus foetidissimus Migula. (*Bacillus pyogenes foetidus liquefaciens* Lanz, Cent. f. Bakt., *14*, 1893, 269; *Bacterium pyogenes foetidus liquefaciens* Chester, Ann. Rept. Del. Col. Agr. Exp. Sta., *9*, 1897, 92; Migula, Syst. d. Bakt., *2*, 1900, 643.) From a brain abscess.

Bacillus fortissimus Weiss. (Arb. bakt. Inst. Karlsruhe, *2*, Heft 3, 1902, 209.) From asparagus and brewer's grain infusions.

Bacillus fuliginosus Weiss. (Arb. bakt. Inst. Karlsruhe, *2*, Heft 3, 1902, 224.) From vegetable infusions.

Bacillus fulvus Edington. (Edington, Brit. Med. Jour., June 11, 1887, 1262; not *Bacillus fulvus* Zimmermann, Bakt. unserer Trink- u. Nutzwässer, Chemnitz, *1*, 1890, 44; not *Bacillus fulvus* Migula, Syst. d. Bakt., *2*, 1900, 844.) Associated with cases of scarlatina. Not pathogenic.

Bacillus fulvus Migula. (*Bacillus tuberigenus 4*, Gonnermann, Landwirtsch. Jahrb., *23*, 1894, 656; Migula, Syst. d. Bakt., *2*, 1900, 844; not *Bacillus fulvus* Zimmermann, Bakt. unserer Trink- u. Nutzwässer, Chemnitz, *1*, 1890, 44.) From root nodules on lupine.

Bacillus fumeus Migula. (No. 5, Lembke, Arch. f. Hyg., *29*, 1897, 313; Migula, Syst. d. Bakt., *2*, 1900, 787.) From feces.

Bacillus fumosus Migula. (No. 4, Lembke, Arch. f. Hyg., *29*, 1897, 312; Migula, Syst. d. Bakt., *2*, 1900, 788.) From feces.

Bacillus fungosus Weiss. (Arb. bakt. Inst. Karlsruhe, *2*, Heft 3, 1902, 255.) From fermenting beets.

Bacillus fuscans Miller. (Miller, Die Mikroorganismen der Mundhöhle, Leipzig, 1889, 70.) From the mouth.

Bacillus fuscescens Migula. (*Bacillus fuscus limbatus* Scheibenzuber, Allgem. Wiener med. Zeitung, *34*, 1889, 171;

Bacterium fuscus limbatus Chester, Ann. Rept. Del. Col. Agr. Exp. Sta., *9*, 1897, 117; Migula, Syst. d. Bakt., *2*, 1900, 836; *Bacterium fuscescens* Chester, Man. Determ. Bact., 1901, 179; *Bacillus fuscus* Chester, *ibid.*, 261; not *Bacillus fuscus* Flügge, Die Mikroorganismen, 2 Aufl., 1886, 290; not *Bacillus fuscus* Zimmermann, Bakt. unserer Trink- u. Nutzwässer, Chemnitz, *1*, 1890, 70.) From rotten eggs.

Bacillus galtieri Trevisan. (Microbe pathogène chromo-aromatique du porc, Galtier, Compt. rend. Acad. Sci. Paris, *106*, 1888, 1368; Trevisan, I generi e le specie delle Batteriacee, 1889, 14; *Bacillus chromoaromaticus* Eisenberg, Bakt. Diag., 3 Aufl., 1891, 360; *Bacterium chromo-aromaticus* Chester, Ann. Rept. Del. Col. Agr. Exp. Sta., *9*, 1897, 119; *Bacillus helvolus* Chester, Man. Determ. Bact., 1901, 264; not *Bacillus helvolus* Zimmermann, Bakt. unserer Trink- u. Nutzwässer, Chemnitz, *1*, 1890, 52.) From lesions in a case of broncho-pneumonia in hogs.

Bacillus gasoformans Pribram. (*Bacterium aquatile gasoformans non liquefaciens* von Rigler, Hyg. Rund., *12*, 1902, 482; *Bacterium gasoformans non liquefaciens* von Rigler, *ibid.*, 485 and Cent. f. Bakt., I Abt., Ref., *31*, 1902, 682; *Bacillus aquatilis gasoformans non liquefaciens* Pribram, Klassification der Schizomyceten, Leipzig und Wien, 1933, 83; *ibid.*, 83.) From bottled mineral waters. Similar to coliform bacteria except that it is a yellow chromogen.

Bacillus gaytoni Cheshire. (Bees and Bee Keeping, London, *2*, Part 13, 1886, 543 and 569.) Found in black bees (*Apis mellifera*), i.e., black because of the loss of hairy covering.

Bacillus gelatinosus Migula. (*Bacterium gelatinosum betae* Glaser, Cent. f. Bakt., II Abt., *1*, 1895, 879; Migula, Syst. d. Bakt., *2*, 1900, 805.) From beet juice.

Bacillus gelatogenes Black. (Trans. Ill. State Dental Soc., *22*, 1886, 187.) From the mouth.

Bacillus geton Trevisan. (Bacille de l'eau *b*, Babes, in Cornil and Babes, Les Bactéries, 2nd ed., 1886, 168; Trevisan, I generi e le specie delle Batteriacee, 1889, 19.) From water.

Bacillus gigas Goot. (Goot, Med. Proefstat. voor de Java Suikerindustrie, Pt. 5, No. 10, 60 pp., quoted from Steinhaus, Bact. Assoc. Extracell. with Insects and Ticks, Minneapolis, 1942, 58; not *Bacillus gigas* Zeissler and Rassefeld, Arch. f. wiss. u. prakt. Tierheilk., *59*, 1929, 419.) From larval and adult stages of a beetle (*Adoretus compressus*).

Bacillus (?) *gingivae* Migula. (*Bacterium gingivae pyogenes* Miller, Die Mikroorganismen der Mundhöhle, Leipzig, 1889, 217; *Bacillus pyogenes gingivae* Kruse, in Flügge, Die Mikroorganismen, 3 Aufl., *2*, 1896, 287; Migula, Syst. d. Bakt., *2*, 1900, 642.) From the oral cavity.

Bacillus glaucus Maschek. (Maschek, Bakt. Untersuch. d. Leitmeritz. Trinkwässer, Jahresber. d. Oberrealschule zu Leitmeritz, 1887; quoted from Sternberg, Man. of Bact., 1893, 637; *Bacterium glaucus* Chester, Ann. Rept. Del. Col. Agr. Exp. Sta., *9*, 1897, 116.) From water.

Bacillus globosus Migula. (*Bacterium A*, Peters, Botan. Zeit., *47*, 1889; Migula, Syst. d. Bakt., *2*, 1900, 798.) From fermenting dough.

Bacillus globulosus Weiss. (Arb. bakt. Inst. Karlsruhe, *2*, Heft 3, 1902, 253.) From sauerkraut and bean infusions.

Bacillus gonnermanni Migula. (*Bacillus tuberigenus II*, Gonnermann, Landwirtsch. Jahrb., *23*, 1894, 656; Migula, Syst. d. Bakt., *2*, 1900, 682.) From root nodules on a lupine.

Bacillus gortynae Paillot. (Compt. rend. Acad. Sci., Paris, *157*, 1913, 611.) From caterpillars of *Gortyna ochracea*. A coccobacillus.

Bacillus gracilescens Henrici. (Arb. bakt. Inst. Karlsruhe, *1*, Heft 1, 1894, 26.) From Swiss cheese.

Bacillus gracilis Kern. (Kern, Arb. bakt. Inst. Karlsruhe, *1*, Heft 4, 1896, 421; not *Bacillus gracilis* Zimmermann,

Bakt. unserer Trink- u. Nutzwässer, Chemnitz, *1*, 1890, 50; *Bacillus gracilior* Migula, Syst. d. Bakt., *2*, 1900, 664.) From the stomach and intestines of birds.

Bacillus gracilis aerobiens Vaughan. (Amer. Jour. Med. Sci., *104*, 1892, 187.) From water.

Bacillus gracilis anaerobiescens Vaughan. (Amer. Jour. Med. Sci., *104*, 1892, 187.) From water.

Bacillus gracilis cadaveris Sternberg. (Sternberg, Man. of Bact., 1893, 733; *Bacterium gracilis cadveris* Chester, Ann. Rept. Del. Col. Agr. Exp. Sta., *9*, 1897, 84.) From the human liver.

Bacillus grandis Trevisan. (Bacille de l'air *h*, Babes, in Cornil and Babes, Les Bactéries, 2nd ed., 1886, 150; Trevisan, I generi e le specie delle Batteriacee, 1889, 20.) From air.

Bacillus granulatus Chester. (*Bacillus aquatilis solidus* Lustig, Diag. Bakt. d. Wassers, 1893; *Bacterium aquatilis solidus* Chester, Ann. Rept. Del. Col. Agr. Exp. Sta., *9*, 1897, 76; Chester, Man. Determ. Bact., 1901, 223.) From water.

Bacillus granulosus Losski. (Losski, Inaug. Diss., Dorpat, 1893, 25; not *Bacillus granulosus* Russell, Ztschr. f. Hyg., *11*, 1892, 99; not *Bacillus granulosus* Gerstner, Arb. bakt. Inst. Karlsruhe, *1*, Heft 2, 1894, 167; *Bacillus subgranulosus* Migula, Syst. d. Bakt., *2*, 1900, 820.) From sand on the Riga coast.

Bacillus graveolens Bordoni-Uffreduzzi. (Bordoni-Uffreduzzi, Fortschr. d. Med., *4*, 1886, 157; not *Bacillus graveolens* Russell, Ztschr. f. Hyg., *11*, 1892, 99; not *Bacillus graveolens* Gottheil, Cent. f. Bakt., II Abt., *7*, 1901, 496; *Bacterium graveolens* Eisenberg, Bakt. Diag., 3 Aufl., 1891, 108.) From skin between the toes.

Bacillus grawitzi Trevisan. (Bacillus der Acne Contagiosa des Pferdes, Dieckerhoff and Grawitz, Arch. f. path. Anat., *102*, 1885, 148; Trevisan, I generi e le specie delle Batteriacee, Milan, 1889, 13; *Bacillus acnes contagiosae* Kruse, in Flügge, Die Mikroorganismen, 3 Aufl., *2*, 1896, 445; *Bacterium acnes contagiosae* Chester, Ann. Rept. Del. Col. Agr. Exp. Sta., *9*, 1897, 89; *Bacterium acnes* Migula, Syst. d. Bakt., *2*, 1900, 385; *Bacterium grawitzii* Chester, Man. Determ. Bact., 1901, 154.) From acne pustles in horses.

Bacillus griseus Migula. (Grauer Bacillus, Keck, Inaug. Diss., Dorpat, 1891, 51; Migula, Syst. d. Bakt., *2*, 1900, 785.) From water.

Bacillus haematoides Wright. (Wright, Mem. Nat. Acad. Sci., *7*, 1895, 448; *Bacterium haematoides* Chester, Ann. Rept. Del. Col. Agr. Exp. Sta., *9*, 1897, 115.) From river water.

Bacillus hajeki Trevisan. (*Bacillus foetidus ozaenae* Hajek, Münch. med. Wochnschr., 1887 and Berliner klin. Wochnschr., 1888, 662; Trevisan, I generi e le specie delle Batteriacee, 1889, 16; *Bacillus ozaenae* Migula, Syst. d. Bakt., *2*, 1900, 645; not *Bacillus ozaenae* Abel, Cent. f. Bakt., *13*, 1893, 167; *Bacterium foetidus ozaenae* Chester, Ann. Rept. Del. Col. Agr. Exp. Sta., *9*, 1897, 134.) From nasal mucus in human ozena.

Bacillus halobicus Horowitz-Wlassowa. (Ztschr. f. Unters. d. Lebensm., *62*, 1931, 597.) From brines used in salting fish.

Bacillus halophilus Russell. (Russell, Ztschr. f. Hyg., *11*, 1891, 200; *Bacterium halophilus* Chester, Ann. Rept. Del. Col. Agr. Exp. Sta., *9*, 1897, 93 and 135.) From sea water and marine mud.

Bacillus havaniensis Migula. (*Bacillus havaniensis liquefaciens* Sternberg, Man. of Bact., 1893, 686; *Bacterium havaniensis liquefaciens* Chester, Ann. Rept. Del. Col. Agr. Exp. Sta., *9*, 1897, 97; Migula, Syst. d. Bakt., *2*, 1900, 725; not *Bacillus havaniensis* Sternberg, *loc. cit.*, 718.) From the skin.

Bacillus helvolus granulatus Dyar. (Ann. N. Y. Acad. Sci., *8*, 1895, 374.) Apparently a variety of *Bacillus helvolus* Zimmermann.

Bacillus heminecrobiophilus Arloing. (Compt. rend. Acad. Sci., Paris, *107*, 1888, 1169 and *108*, 1889, 458.) From the

lymph glands of an experimental guinea pig.

Bacillus hepaticus fortuitus Sternberg. (Sternberg, Man. of Bact., 1893, 649; *Bacterium hepaticus fortuitus* Chester, Ann. Rept. Del. Col. Agr. Exp. Sta., *9*, 1897, 136.) From the liver of a yellow-fever cadaver.

Bacillus herrmanni Migula. (Ein neuer Kapselbacillus, Herzfeld and Herrmann, Hyg. Rundschau, *5*, 1895, 642; Migula, Syst. d. Bakt., *2*, 1900, 647.) From a nasal secretion.

Bacillus hofmanni Migula. (Hofmann, Wochnschr. f. Forstwirtsch., 1891, No. 1-6 and No. 35-39; Migula, Syst. d. Bakt., *2*, 1900, 742.) From the larvae of the nun moth (*Lymantria monacha*).

Bacillus hudsonii Dyar. (Ann. N. Y. Acad. Sci., *8*, 1895, 369; *Bacterium hudsonii* Chester, Ann. Rept. Del. Col. Agr. Exp. Sta., *9*, 1897, 106.) From air.

Bacillus humilis Trevisan. (Bactérie de l'air No. 1, Babes, in Cornil and Babes, Les Bactéries, 2nd ed., 1886, 140; Trevisan, I generi e le specie delle Batteriacee, 1889, 20.) From air.

Bacillus hydrocharis Trevisan. (Bacille de l'eau *c*, Babes, in Cornil and Babes, Les Bactéries, 2nd ed., 1886, 168; Trevisan, I generi e le specie delle Batteriacee, 1889, 19.) From water.

Bacillus hydrosulfureus Migula. (*Bacillus oogenes hydrosulfureus* ζ Zörkendörfer, Arch. f. Hyg., *16*, 1893, 388; Migula, Syst. d. Bakt., *2*, 1900, 695.) From hens' eggs.

Bacillus icterogenes Kruse. (Guarnieri, Acc. med. Roma, 87/88 and Vincent, Semaine médicale, 1893, 29; Kruse, in Flügge, Die Mikroorganismen, 3 Aufl., *2*, 1896, 372; *Bacterium icterogenes* Chester, Ann. Rept. Del. Col. Agr. Exp. Sta., *9*, 1897, 69.) From the liver and blood in cases of acute yellow atrophy.

Bacillus incanus Pohl. (Pohl, Cent. f. Bakt., *11*, 1892, 142; *Bacterium incanus* Chester, Ann. Rept. Del. Col. Agr. Exp. Sta., *9*, 1897, 99; *Bacterium incannum* (sic) Chester, Man. Determ. Bact., 1901, 157.) From swamp water.

Bacillus indigogenus Alvarez. (Alvarez, Compt. rend. Acad. Sci., Paris, *105*, 1887, 286; *Bacterium indigogenus* Chester, Ann. Rept. Del. Col. Agr. Exp. Sta., *9*, 1897, 136.) From an infusion of leaves of the indigo plant.

Bacillus innesi Trevisan. (Bacille de l'éléphantiasis des Arabes, Innes, Bull. Ist. Égypt. de 1886, Cairo, 1887; Trevisan, I generi e le specie delle Batteriacee, 1889, 13.) From the blood in cases of elephantiasis in Egypt.

Bacillus inodorus Trevisan. (I generi e le specie delle Batteriacee, 1889, 16.) From pus.

Bacillus intestinus motilis Sternberg. (Sternberg, Man. of Bact., 1893, 649; *Bacterium intestinus motilis* Chester, Ann. Rept. Del. Col. Agr. Exp. Sta., *9*, 1897, 74.) From intestines of yellow fever cadavers.

Bacillus inutilis Dyar. (Ann. N. Y. Acad. Sci., *8*, 1895, 364.) From air.

Bacillus kappa Dyar. (Ann. N. Y. Acad. Sci., *8*, 1895, 375.) From diseased larva of a moth (*Scoliopteryx libatrix*).

Bacillus klebsii Trevisan. (*Bacillus typhosus* Klebs, Handb. d. path. Anat., 1880 and Arch. f. exper. Pathol. u. Pharmac., *13*, 1881, Heft 5-6; Trevisan, Car. di alc. nuov. gen. di Battr., 1885, 10; Trevisan, I generi e le specie delle Batteriacee, 1889, 14; not *Bacillus typhosus* Zopf, Die Spaltpilze, 3 Aufl., 1885, 126.) From an intestinal necrosis.

Bacillus kleckii Migula. (*Bacillus butyri II*, v. Klecki, Cent. f. Bakt., *15*, 1894, 360; Migula, Syst. d. Bakt., *2*, 1900, 810.) From rancid butter.

Bacillus kleinii Trevisan. (Bacillus de la diarrhée choleriforme, Klein, Micro-organisms and Disease, 1885, 87; Trevisan, in DeToni and Trevisan, in Saccardo, Sylloge Fungorum, *8*, 1889, 946; not *Bacillus kleinii* Migula, Syst. d. Bakt., *2*, 1900, 766; not *Bacillus kleinii* Buchanan and Hammer, Iowa Agr. Exp. Sta. Res. Bull. 22, 1915, 276.) From the blood in fatal cases of choleraic diarrhoea.

Bacillus kleinii Migula. (Ein neuer

Bacillus des malignen Oedems, Klein, Cent. f. Bakt., *10*, 1891, 186; *Bacillus pseudo-oedematis maligni* Sanfelice, Ztschr. f. Hyg., *14*, 1893, 353; *Bacillus oedematis aerobicus* Sternberg, Man. of Bact., 1893, 465; *Bacillus oedematis aerobius* Kruse, in Flügge, Die Mikroorganismen, 3 Aufl., *2*, 1896, 244; *Bacterium oedematis aerobius* Chester, Ann. Rept. Del. Col. Agr. Exp. Sta., *9*, 1897, 75; Migula, Syst. d. Bakt., *2*, 1900, 766; not *Bacillus kleinii* Trevisan, in De-Toni and Trevisan, in Saccardo, Sylloge Fungorum, *8*, 1889, 946; not *Bacillus kleinii* Buchanan and Hammer, Iowa Agr. Exp. Sta. Res. Bull. 22, 1915, 276; *Bacillus aerobius* Chester, Man. Determ. Bact., 1901, 221.) From a guinea pig inoculated with soil.

Bacillus kornii Chester. (Bacillus bei einem Leberabscess, Korn, Cent. f. Bakt., *21*, 1897, 438; Chester, Man. Determ. Bact., 1901, 252.) From a case of liver abscess.

Bacillus lactis Chester. (Bacillus b, Guillebeau, Ann. Microg., *11*, 1898–1899, 225; Chester, Man. Determ. Bact., 1901, 238; not *Bacillus lactis* Neide, Cent. f. Bakt., II Abt., *12*, 1904, 337.) From milk.

Bacillus lactofoetidus Migula. (*Bacillus foetidus lactis* Jensen, 22de Beretning fra den Kgl. Veterin og Landbohöjskoles Laboratorium for landökonomiske Forsoeg, Copenhagen, 1891, 15; Migula, Syst. d. Bakt., *2*, 1900, 740.) From tainted milk and butter.

Bacillus lanceolatus Mattes. (Sitzungsber. d. Gesells. z. Beförderung d. gesam. Naturw. z. Marburg, *62*, 1927, 381–417.) From benign foulbrood of bees (*Apis mellifera*).

Bacillus larvicida Dyar. (Ann. N. Y. Acad. Sci., *8*, 1895, 377; *Bacterium larvicida* Chester, Ann. Rept. Del. Col. Agr. Exp. Sta., *9*, 1897, 103.) From the exudate of a diseased larva of a moth (*Clisiocampa fragilis*).

Bacillus lassari Trevisan. (Bacillus des lichen ruber, Lassar, see Flügge, Die Mikroorganismen, 2 Aufl., 1886, 239; Trevisan, I generi e le specie delle Batteriacee, 1889, 14.) From lichen ruber, a skin disease.

Bacillus lentiformis Kern. (Arb. bakt. Inst. Karlsruhe, *1*, Heft 4, 1896, 418.) From the stomach and intestines of birds.

Bacillus leptinotarsae White. (Proc. Ent. Soc. Wash., *30*, 1928, 71; Jour. Agr. Res., *51*, 1935, 223.) From diseased larvae of the Colorado potato-beetle (*Leptinotarsa decemlineata*).

Bacillus lesagei Trevisan. (Bacille de la diarrhée verte des enfants, Lesage, Bull. Acad. Méd., Paris, October, 1887; Trevisan, I generi e le specie delle Batteriacee, 1889, 14; *Bacillus viridis* Kruse, in Flügge, Die Mikroorganismen, 3 Aufl., *2*, 1896, 292; *Bacterium viridis* Chester, Ann. Rept. Del. Col. Agr. Exp. Sta., *9*, 1897, 118.) Associated with green diarrhoea of children.

Bacillus limbatus Migula. (*Bacillus limbatus butyri* von Klecki, Cent. f. Bakt., *15*, 1894, 359; Migula, Syst. d. Bakt., *2*, 1900, 62.) From rancid butter.

Bacillus limicola Russell. (Bot. Gaz., *18*, 1893, 383.) From sea water and marine mud at Woods Hole, Massachusetts.

Bacillus lineatus Eckstein. (Ztschr. f. Forst- u. Jagdwesen, *26*, 1894, 17.) From larvae of the nun moth (*Lymantria monacha*).

Bacillus lineatus Migula. (Bakterie V, Weigmann and Zirn, Cent. f. Bakt., *15*, 1894, 467; Migula, Syst. d. Bakt., *2*, 1900, 806; not *Bacillus lineatus* Eckstein, Ztschr. f. Forst- und Jagdwesen, *26*, 1894, 17.) From soapy milk.

Bacillus liparis Paillot. (Compt. rend. Acad. Sci., Paris, *164*, 1917, 527.) From larvae of the gypsy moth (*Porthetria (Lymantria) dispar*).

Bacillus liquefaciens Doyen. (*Bacillus urinae liquefaciens* Doyen, Jour. d. connaiss. médic., 1889, 108; Doyen, *idem*; not *Bacillus liquefaciens* Eisenberg, Bakt. Diag., 3 Aufl., 1891, 112.) From urine.

Bacillus liquefaciens Migula. (*Bacil-*

lus sulcatus liquefaciens Kruse, in Flügge, Die Mikroorganismen, 3 Aufl., *2*, 1896, 318; Migula, Syst. d. Bakt., *2*, 1900, 723; not *Bacillus liquefaciens* Eisenberg, Bakt. Diag., 3 Aufl., 1891, 112.) From water.

Bacillus liquefaciens albus Vaughan. (Amer. Jour. Med. Sci., *104*, 1892, 185.) From water.

Bacillus liquefaciens communis Sternberg. (Sternberg, Man. of Bact., 1893, 686; *Bacterium liquefaciens communis* Chester, Ann. Rept. Del. Col. Agr. Exp. Sta., *9*, 1897, 137.) From the feces of yellow fever patients. Considered by Chester (*loc. cit.*, 91) to be synonymous with *Bacillus aquatilis communis* Kruse.

Bacillus liquidus communis Sternberg. (Manual of Bact., 1893, 686.) From feces.

Bacillus litorosus Russell. (Bot. Gaz., *18*, 1893, 444.) From sea water and marine mud at Woods Hole, Massachusetts.

Bacillus loxiacida Tartakowsky. (Arch. d. Veterinarwiss., 1888; quoted from Chester, Man. Determ. Bact., 1901, 211.) Associated with an infectious disease of crossbills.

Bacillus lucidus Migula. (No. 8, Lembke, Arch. f. Hyg., *26*, 1896, 303; Migula, Syst. d. Bakt., *2*, 1900, 674.) From feces.

Bacillus lupi Trevisan. (I generi e le specie delle Batteriacee, 1889, 12.) From lupus, a skin disease.

Bacillus lupini Migula. (*Bacillus tuberigenus 7*, Gonnermann, Landwirtsch. Jahrb., *23*, 1894, 657; Migula, Syst. d. Bakt., *2*, 1900, 793.) From root nodules on lupine.

Bacillus lustigii Trevisan. (Bacillo inoffensivo del Mytilus edulis, Lustig, Arch. per le sci. med., *12*, 1887, 17; Trevisan, see DeToni and Trevisan, in Saccardo, Sylloge Fungorum, *8*, 1889, 958; not *Bacillus lustigii* Carbone and Venturelli, Boll. Ist. Sieroter., Milan, *4*, 1925, 59.) From the liver of a mussel (*Mytilus edulis*).

Bacillus luteo-albus Beijerinck. (Botan. Zeit., *46*, 1888, 749.) From root nodules on legumes.

Bacillus lutetiensis Chester. (*Bacillus violaceus lutetiensis* Kruse, in Flügge, Die Mikroorganismen, 3 Aufl., *2*, 1896, 311; Chester, Man. Determ. Bact., 1901, 306.) From water.

Bacillus luteus Flügge. (Die Mikroorganismen, 2 Aufl., 1886, 290; not *Bacillus luteus* von Dobrzyniecki, Cent. f. Bakt., I Abt., *21*, 1897, 835; not *Bacillus luteus* Garbowski, Cent. f. Bakt., II Abt., *19*, 1907, 641.) From air.

Bacillus lymantriae Picard and Blanc. (Picard and Blanc, Compt. rend. Acad. Sci., Paris, *157*, 1913, 80; *Bacillus lymantria α* Paillot, *ibid.*, *168*, 1919, 258; *Bacillus (Bacterium) lymantriae* Paillot, L'infection chez les insectes, 1933, 131; *Coccobacillus lymantriae* Steinhaus, Catalogue of Bacteria Associated Extracellularly with Insects and Ticks, Minneapolis, 1942, 64 and 183.) From diseased larvae of the gypsy moth (*Porthetria (Lymantria) dispar*).

Bacillus lymantriae β Paillot. (Compt. rend. Acad. Sci., Paris, *168*, 1919, 258.) From diseased larvae of the gypsy moth (*Porthetria (Lymantria) dispar*).

Bacillus lymantricola adiposus Paillot. (Compt. rend. Acad. Sci., Paris, *168*, 1919, 258; *Bacterium lymantricola adiposus* Paillot, L'infection chez les insectes, 1933, 135.) From caterpillars of *Porthetria (Lymantria) dispar*.

Bacillus madidus Migula. (No. 5, Lembke, Arch. f. Hyg., *26*, 1896, 300; Migula, Syst. d. Bakt., *2*, 1900, 812.) From bread.

Bacillus maggiorae DeToni and Trevisan. (*Bacillus B*, Maggiora, Giorn. Soc. ital. d'Igiene, *11*, 1889, 340; DeToni and Trevisan, in Saccardo, Sylloge Fungorum, *8*, 1889, 968.) From the skin of the human foot and from air.

Bacillus major Doyen. (*Bacillus urinae major* Doyen, Jour. d. connaiss. médic., 1889, 107; Doyen, *ibid.*, 108.) From urine.

Bacillus malariae Klebs and Tommasi-Crudeli. (Arch. f. exper. Pathol., *2*,

1879.) From swamp soil. See Sternberg, Man. of Bact., 1893, 523.

Bacillus mammitidis Migula. (*Bacillus a*, Guillebeau, Ann. de Microg., *2*, 1890, No. 8; Migula, Syst. d. Bakt., *2*, 1900, 810.) From the milk of cows having mastitis.

Bacillus manganicus Beijerinck. (Folia Microbiol., Delft, *2*, 1913, 130.) From soil. Motile. Is able to oxidize manganese carbonate.

Bacillus margarineus Migula. (*Diplococcus capsulatus margarineus* Jolles and Winkler, Ztschr. f. Hyg., *20*, 1895, 103; Migula, Syst. d. Bakt., *2*, 1900, 694.) From margarine.

Bacillus maricola Migula. (*Halibacterium polymorphum* Fischer, Die Bakterien des Meeres, 1894, 36; Migula, Syst. d. Bakt., *2*, 1900, 709.) From sea water.

Bacillus marsilliensis Kruse. (Bacillus of Marseilles swine plague, Rietsch and Jobert, Compt. rend. Acad. Sci., Paris, *106*, 1888, 1096; Kruse, in Flügge, Die Mikroorganismen, 3 Aufl., *2*, 1896, 405; *Bacterium marsiliensis* Chester, Ann. Rept. Del. Col. Agr. Exp. Sta., *9*, 1897, 67.) Associated with a disease of swine.

Bacillus martinez Sternberg. (Sternberg, Man. of Bact., 1893, 651; *Bacillus martinezii* Dyar, Ann. N. Y. Acad. Sci., *8*, 1895, 364; *Bacterium martinezii* Chester, Ann. Rept. Del. Col. Agr. Exp. Sta., *9*, 1897, 83.) From the liver of a yellow fever cadaver. Dyar isolated an organism from the air to which he applied Sternberg's name as the descriptions of the two species did not disagree.

Bacillus meleagridis Migula. (McFadyean, Jour. Comp. Path. and Therap., *6*, 1893, 334; Migula, Syst. d. Bakt., *2*, 1900, 770; *Bacillus meleagris* Chester, Man. Determ. Bact., 1901, 220.) The cause of epizootic pneumo-carditis in turkeys.

Bacillus melleus Schroeter. (In Cohn, Kryptog. Flora v. Schlesien, *3*, 1, 1886, 158.) From feces and other sources.

Bacillus melolonthae Chatton. (Compt. rend. Acad. Sci., Paris, *156*, 1913, 1708.) From diseased cockchafers (*Melolontha melolontha*).

Bacillus melolonthae liquefaciens α, β and γ Paillot. (Compt. rend. Acad. Sci., Paris, *167*, 1918, 1046; Annales des Épiphyties, *8*, 1922, 108–110; *B. melolonthae liquefaciens* α, β and γ Paillot, L'infection chez les insectes, 1933, 173, 196 and 189 respectively. According to the index the *B.* is used for *Bacterium*.) From diseased cockchafers (*Melolontha melolontha*).

Bacillus melolonthae non-liquefaciens α, β and γ Paillot. (Compt. rend Acad. Sci., Paris, *163*, 1916, 553; Annales des Épiphyties, *8*, 1922, 111–113.) From diseased cockchafer (*Melolontha melolontha*).

Bacillus melolonthae non-liquefaciens δ Paillot. (Compt. rend Acad. Sci., Paris, *167*, 1918, 1046; Annales des Épiphyties, *8*, 1922, 113.) From diseased cockchafers (*Melolontha melolontha*).

Bacillus melolonthae non-liquefaciens ϵ Paillot. (Compt. rend. Acad. Sci., Paris, *169*, 1919, 1122; Annales des Épiphyties, *8*, 1922, 114.) From diseased cockchafers (*Melolontha melolontha*).

Bacillus membranaceus Kern. (Arb. bakt. Inst. Karlsruhe, *1*, Heft 4, 1896, 407.) From the stomach and intestines of a bird.

Bacillus meningitidis Migula. (*Bacillus aerogenes meningitidis* Centanni, Arch. per le scienze mediche, *17*, 1893, No. 1; *Bacterium meningitidis aerogenes* Chester, Ann. Rept. Del. Col. Agr. Exp. Sta., *9*, 1897, 96; Migula, Syst. d. Bakt., *2*, 1900, 642; *Bacillus radiatus* Chester, Man. Determ. Bact., 1901, 241.) From two cases of meningitis.

Bacillus metabolicus DeToni and Trevisan. (*Bacillus H*, Maggiora, Giorn. Soc. ital. d'Igiene, *11*, 1889, 350; DeToni and Trevisan, in Saccardo, Sylloge Fungorum, *8*, 1889, 968.) From the skin of the human foot.

Bacillus metaflavus Castellani. (Proc. Soc. Expt. Biol. and Med., *25*, 1928, 539.) From the human skin.

Bacillus minimus Eckstein. (Ztschr. f. Forst- u. Jagdwesen, *26*, 1894, 16.) From caterpillars of the nun moth (*Lymantria monacha*).

Bacillus minutissimus Migula. (*Bacillus aureus minutissimus* Kruse, in Flügge, Die Mikroorganismen, 3 Aufl., *2*, 1896, 441; Migula, Syst. d. Bakt., *2*, 1900, 833.) From air.

Bacillus mitidus Henrici. (Arb. bakt. Inst. Karlsruhe, *1*, Heft 1, 1894, 29.) From Gouda cheese.

Bacillus mobilissimus Migula. (*Bacillus oogenes hydrosulfureus δ*, Zörkendörfer, Arch. f. Hyg., *16*, 1893, 390; Migula, Syst. d. Bakt., *2*, 1900, 791.) From hens' eggs.

Bacillus mollis Doyen. (*Bacillus urinae mollis* Doyen, Jour. d. connaiss. médic., 1889, 107; Doyen, *ibid.*, 108.) From urine.

Bacillus morulans Boucquet. (Phytopath., *7*, 1917, 286.) From diseased sugar beets. Associated with curly top of sugar beet.

Bacillus nottei Trevisan. (Motte and Protopopoff, Wratsch., 1887, No. 21, 415; abst. in Cent. f. Bakt., *2*, 1887, 450; Trevisan, I generi e le specie delle Batteriacee, 1889, 13.) Associated with a rabies-like disease of rabbits and dogs.

Bacillus (?) *multiformis* Castellani. (Proc. Soc. Exp. Biol. and Med., *25*, 1928, 539.) From the human skin.

Bacillus murinus Chester. (Bacillus of rat plague, Issatschenko, Cent. f. Bakt., *23*, 1898, 873; Chester, Man. Determ. Bact., 1901, 224; not *Bacillus murinus* Schroeter, in Cohn, Kryptog. Flora v. Schlesien, *3*, 1886, 162.) From the spleen and liver of rats attacked in St. Petersburg by a plague.

Bacillus mycogenes Edwards. (Jour. Inf. Dis., *2*, 1905, 431; *Bacterium mucogenum* Edwards, *idem.*) From exudate of wound infections. Belongs to the *Bacillus mucosus capsulatus* group.

Bacillus mytili Trevisan. (Bacillo patogeno del Mytilus edulis, Lustig, Arch. per le Sci. med., *12*, 1887, 17; Trevisan, see DeToni and Trevisan, in Saccardo, Sylloge Fungorum, *8*, 1889, 958.) From the liver of a mussel (*Mytilus edulis*).

Bacillus naphthalinicus liquefaciens Tausson. (Planta, *4*, 1927, 214.) From oil-soaked soils at Baku, Russia. Oxidizes naphthalene.

Bacillus naphthalinicus non-liquefaciens Tausson. (Planta, *4*, 1927, 214.) From oil-soaked soils at Baku, Russia. Oxidizes naphthalene.

Bacillus nebulosus Migula. (*Bacillus tuberigenus 3*, Gonnermann, Landwirtsch. Jahrb., *23*, 1894, 656; Migula, Syst. d. Bakt., *2*, 1900, 844; not *Bacillus nebulosus* Wright, Mem. Nat. Acad. Sci., 7, 1894, 465; not *Bacillus nebulosus* Hallé, Thèse de Paris, 1898; not *Bacillus nebulosus* Vincent, Ann. Inst. Past., *21*, 1907, 69; not *Bacillus nebulosus* Goresline, Jour. Bact., *27*, 1934, 52.) From root nodules on lupine.

Bacillus necans Trevisan. (Bacille consécutif au charbon, Babes, in Cornil and Babes, Les Bactéries, 2nd ed., 1886, 231; Trevisan, I generi e le specie delle Batteriacee, 1889, 14.) From rabbits dead from anthrax.

Bacillus nephriticus Trevisan. (Bacille de la néphrite bactérienne, Babes, in Cornil and Babes, Les Bactéries, 2nd ed., 1886, 373; Trevisan, I generi e le specie delle Batteriacee, 1889, 14.) From urine in cases of nephritis.

Bacillus neurotomae Paillot. (Compt. rend. Acad. Sci., Paris, *178*, 1924, 247; probably identical with *Bacterium neurotomae* Paillot, L'infection chez les insectes, 1933, 146.) From diseased larvae of a sawfly (*Neurotoma nemoralis* L.).

Bacillus nitens Migula. (*Bacillus oogenes hydrosulfureus ι*, Zörkendörfer, Arch. f. Hyg., *16*, 1893, 390; Migula, Syst. d. Bakt., *2*, 1900, 793.) From hens' eggs.

Bacillus ochroleucus Migula. (*Bacillus oogenes hydrosulfureus ε*, Zörkendörfer, Arch. f. Hyg., *16*, 1893, 387; Migula, Syst. d. Bakt., *2*, 1900, 844.) From hens' eggs.

Bacillus odoratus Weiss. (Weiss, Arb. bakt. Inst. Karlsruhe, *2*, 1902, 243; not

Bacillus odoratus Migula, Syst. d. Bakt., *2*, 1900, 686; *Bacterium odoratum* Omeliansky, Jour. Bact., *8*, 1923, 394.) From fermented beets.

Bacillus odorificans Migula. (Weisser stinkender Bacillus, Maschek, Bakt. Untersuch. d. Leitmeritzer Trinkwässer, Leitmeritz, 1887; Migula, Syst. d. Bakt., *2*, 1900, 711.) From water. Intense odor resembling that of liquid manure.

Bacillus odorificus Omeliansky. (Jour. Bact., *8*, 1923, 393.) Probably intended for *Bacillus odorificans* Migula.

Bacillus odorus Henrici. (Arb. bakt. Inst. Karlsruhe, *1*, Heft 1, 1894, 30.) From cream cheese.

Bacillus oonergasius Trevisan. (Bacille du mucus intestinal normal *c*, Babes, in Cornil and Babes, Les Bactéries, 2nd ed., 1886, 153; Trevisan, I generi e le specie delle Batteriacee, 1889, 15.) From normal intestinal mucus.

Bacillus osteomyeliticus Trevisan. (Bacille de l'ostéomyélite, Rodet; Trevisan, 1884; see Trevisan, I generi e le specie delle Batteriacee, 1889, 16.) From a case of osteomyelitis.

Bacillus oxylacticus Dyar. (Ann. N. Y. Acad. Sci., *8*, 1895, 369.) Culture received from Kràl's laboratory labeled *Bacillus oxylacticus;* also from air.

Bacillus pallescens Migula. (*Bacillus luteus pallescens* Losski, Inaug. Diss., Dorpat, 1893, 44; Migula, Syst. d. Bakt., *2*, 1900, 819.) From garden soil.

Bacillus pallidus Schroeter. (Schroeter, in Cohn, Kryptog. Flora v. Schlesien, *3*, 1, 1886, 158; not *Bacillus pallidus* Bredemann and Heigener, Cent. f. Bakt., II Abt., *93*, 1935, 98.) From cooked potato.

Bacillus panificans Laurent. (Bull. Soc. R. Bot. Belg., 1885, 175.) From fermenting dough.

Bacillus pannosus Kern. (Arb. bakt. Inst. Karlsruhe, *1*, Heft 4, 1896, 409.) From the stomachs and intestines of birds.

Bacillus pansinii Migula. (Bacillus No. 12, Pansini, Arch. f. path. Anat., *122*, 1890, 477; Migula, Syst. d. Bakt., *2*, 1900, 660.) From sputum.

Bacillus parallelus Edson and Carpenter. (Vermont Agr. Exp. Sta. Bull. 167, 1912, 593.) From maple sap. Capsulated. At times feebly fluorescent.

Bacillus paullulus Trevisan. (Bacille de l'air *d*, Babes, in Cornil and Babes, Les Bactéries, 2nd ed., 1886, 149; Trevisan, I generi e le specie delle Batteriacee, 1889, 20.) From air.

Bacillus pectinophorae White and Noble. (Jour. Econ. Entomol., *29*, 1936, 123.) From diseased pink bollworm larvae (*Pectinophora gossypiella*).

Bacillus pediculi Arkwright and Bacot. (Parasitol., *13*, 1921, 26.) From the genital apparatus of the louse (*Pediculus humanus*).

Bacillus pellucidus Doyen. (*Bacillus urinae pellucidus* Doyen, Jour. d. connaiss. médic., 1889, 107; Doyen, *ibid.*, 108; not *Bacillus pellucidus* Kern, Arb. bakt. Inst. Karlsruhe, *1*, Heft 4, 1896, 404.) From urine.

Bacillus perlibratus Beijerinck. (Cent. f. Bakt., *14*, 1893, 831.) From a bean infusion.

Bacillus perronciti Trevisan. (Bacillo della pneumonite nodulare dei vitellini, Perroncito, Parassiti dell'uomo e degli animali utili, 1882, 52; Trevisan, I generi e le specie delle Batteriacee, 1889, 13.) From pulmonary nodules in contagious pneumonia in calves.

Bacillus petersii Migula. (*Bacterium B*, Peters, Botan. Zeit., *47*, 1889; *Bacterium acidi lactici* Kruse, in Flügge, Die Mikroorganismen, 3 Aufl., *2*, 1896, 357; not *Bacterium acidi lactici* Zopf, Die Spaltpilze, 2 Aufl., 1884, 60; not *Bacterium acidi lactici I* and *II* Grotenfelt, Fortschr. d. Med., 7, 1889, 123; not *Bacterium acidi lactici* Migula, in Engler and Prantl, Die natürl. Pflanzenfam., *1*, 1a, 1895, 25; Migula, Syst. d. Bakt., *2*, 1900, 799.) From fermenting dough. Probably *Bacterium levans* Wolffin.

Bacillus phenanthrenicus bakiensis Tausson. (Planta, *5*, 1928, 239.) From

soil. Utilizes phenanthrene and other hydrocarbons.

Bacillus phenanthrenicus guricus Tausson. (Planta, *5*, 1928, 239.) From soil. Utilizes phenanthrene and other hydrocarbons.

Bacillus phenologenes Berthelot. (Ann. Inst. Past., *32*, 1918, 20.) From feces. Forms phenol.

Bacillus pieris agilis Paillot. (Compt. rend. Acad. Sci., Paris, *168*, 1919, 477.) From diseased caterpillars of the cabbage butterfly (*Pieris brassicae*).

Bacillus pieris fluorescens Paillot. (Compt. rend. Acad. Sci., Paris, *168*, 1919, 477; Ann. Épiphyt., *8*, 1922, 124.) From diseased caterpillars of the cabbage butterfly (*Pieris brassicae*).

Bacillus pieris liquefaciens Paillot. (Compt. rend. Acad. Sci., Paris, *168*, 1919 477; *Bacillus pieris liquefaciens α* Paillot, Annales des Épiphyties, *8*, 1922, 125.) From diseased caterpillars of the cabbage butterfly (*Pieris brassicae*). If this author followed his usual custom, this is identical with his *Bact. pieris liquefaciens* in his book, L'infection chez les insectes, 1933, 135.

Bacillus pieris liquefaciens β Paillot. (Annales des Épiphyties, *8*, 1922, 126; name occurs as *B. pieris liquefaciens β* Paillot, L'infection chez les insectes, 1933, 299. According to the index *B.* stands for *Bacterium*.) From diseased caterpillars of the cabbage butterfly (*Pieris brassicae*).

Bacillus pieris non-liquefaciens α Paillot. (Compt. rend. Acad. Sci., Paris, *168*, 1919, 477; *B. pieris non-liquefacins α* Paillot, L'infection chez les insectes, 1933, 135 ff. According to the index *B.* stands for *Bacterium*.) From the cabbage butterfly (*Pieris brassicae*).

Bacillus pieris non-liquefaciens β Paillot. (Compt. rend. Acad. Sci., Paris, *168*, 1919, 474; *B. pieris non-liquefaciens β* Paillot, L'infection chez les insectes, 1933, 299; according to the index, the *B.* stands for *Bacterium*.) From diseased caterpillars of the cabbage butterfly (*Pieris brassicae*).

Bacillus pleomorphus Migula. (*Bacillus murisepticus pleomorphus* Karliński, Cent. f. Bakt., *5*, 1889, 193; *Bacterium murisepticus pleomorphus* Chester, Ann. Rept. Del. Col. Agr. Exp. Sta., *9*, 1897, 102; Migula, Syst. d. Bakt., *2*, 1900, 649; *Bacillus murisepticus* Chester, Man. Determ. Bact., 1901, 247; not *Bacillus murisepticus* Flügge, Die Mikroorganismen, 2 Aufl., 1886, 250.) From pus.

Bacillus plicatus Frankland and Frankland. (Philos. Trans. Roy. Soc. London, *178*, B, 1888, 273; not *Bacillus plicatus* Zimmermann, see Frankland and Frankland, Microorganisms in Water, London, 1894, 459.) From air.

Bacillus plumbeus Migula. (Grau verflüssigender Bacillus, Keck, Inaug. Diss., Dorpat, 1890, 54; Migula, Syst. d. Bakt., *2*, 1900, 719.) From water.

Bacillus pneumo-enteritidis murium Schilling. (Arb. a. d. kaiserl. Gesundheitsamte, *18*, Heft 1, 1900.) From a disease of rats.

Bacillus pneumosepticus Kruse. (Pneumonie bacillus, Klein, Cent. f. Bakt., *5*, 1889, 625; Kruse, in Flügge, Die Mikroorganismen, 3 Aufl., *2*, 1896, 408; not *Bacillus pneumosepticus* Babes, Progrès méd. roumain., *6*, 1889; *Bacterium pneumosepticus* Chester, Ann. Rept. Del. Col. Agr. Exp. Sta., *9*, 1897, 76.) From rusty sputum. Considered the cause of an epidemic of pneumonia in England.

Bacillus poelsii Chester. (Vleeschvergiftung te Rotterdam, Poels and Dhont; Tweede Rapport van de des Kundigen; Chester, Man. Determ. Bact., 1901, 209.) From beef in meat poisoning.

Bacillus pomodoriferus Castellani. (Proc. Soc. Exp. Biol. and Med., *25*, 1928, 540.) From the urine in a case of cystitis and from feces.

Bacillus poncei Glaser. (Ann. Entomol. Soc. Am., *11*, 1918, 19.) Pathogenic for the insects, *Melanoplus femur-rubrum* and *Encoptolopus sordidus*.

Bacillus praepollens Maassen. (Arb. a. d. kaiserl. Gesundheitsamte, *15*,

1899, 507.) From sweat of a cholera patient.

Bacillus primus fullesi Dyar. (Ann. N. Y. Acad. Sci., *8*, 1895, 360; *Bacterium primus fullesi* Chester, Ann. Rept. Del. Col. Agr. Exp. Sta., *9*, 1897, 72.) From a leaf of the pitcher plant (*Sarracenia purpurea*). Regarded by Dyar as identical with Bacillus No. 1, isolated by Fulles (Ztschr. f. Hyg., *10*, 1891, 250) from forest soil.

Bacillus promissus Kern. (Arb. bakt. Inst. Karlsruhe, *1*, Heft 4, 1896, 420.) From the intestines of a dove.

Bacillus proteidis Paillot. (Annales des Épiphyties, *8*, 1922, 130.) From diseased larvae of the cabbage butterfly (*Pieris brassicae*).

Bacillus protervus Trevisan. (Bacillus der Conjunctivalsack *d*, Fick, Microorgan. in Conjunctivalsack, Wiesbaden, 1887; Trevisan, I generi e le specie delle Batteriacee, 1889, 17.) From the conjunctiva.

Bacillus pruddeni Dyar. (Ann. N. Y. Acad. Sci., *8*, 1895, 378.) Found by Dr. Prudden in a case of cystitis.

Bacillus pseudomirabilis Migula. (*Bacillus mirabilis* Tataroff, Inaug. Diss., Dorpat, 1891, 18; Migula, Syst. d. Bakt., *2*, 1900, 818.) From water. According to Migula, Tataroff mistakenly believed that he had Zimmermann's *Bacillus mirabilis*.

Bacillus pseudotuberculosis Migula. (Du Cazal and Vaillard, Ann. Inst. Past., *5*, 1891, 353; *Bacillus pseudotuberculosis liquefaciens* Kruse, in Flügge, Die Mikroorganismen, 3 Aufl., *2*, 1896, 455; Migula, Syst. d. Bakt., *2*, 1900, 644.) From nodules in the peritoneum.

Bacillus pseudotyphosus Kruse. (Lösener, Arb. a. d. kaiserl. Gesundheitsamte, *11*, 1895, 2; Kruse, in Flügge, Die Mikroorganismen, 3 Aufl., *2*, 1896, 383; *Bacterium pseudotyphosus* Chester, Ann. Rept. Del. Col. Agr. Exp. Sta., *9*, 1897, 73; not *Bacterium pseudotyhposum* Migula, Syst. d. Bakt., *2*, 1900, 428.) Isolated by Lösener from peritoneal fluid of a hog, from water, etc.; by Pansini from a liver abscess; by Babes from a variety of sources. Kruse used this as a general name for any typhoid-like organism.

Bacillus pulpae pyogenes Miller. (Miller, Die Mikroorganismen der Mundhöhle, Leipzig, 1889, 219.) From gangrenous pulp of a tooth.

Bacillus punctatus Shul'gina and Kalinicker. (Rep. Bur. Appl. Ent., Leningrad, *3*, No. 1, 1927, 99–104, quoted from Steinhaus, Bact. Assoc. Extracell. with Insects and Ticks, Minneapolis, 1942, 79; not *Bacillus punctatus* Zimmermann, Bakt. unserer Trink- u. Nutzwässer, Chemnitz, I Reihe, 1890, 38.) From the locust (*Locusta migratoria*).

Bacillus puncticulatus Migula. (No. 16, Lembke, Arch. f. Hyg., *29*, 1897, 322; Migula, Syst. d. Bakt., *2*, 1900, 678.) From feces.

Bacillus putidus Kern. (Kern, Arb. bakt. Inst. Karlsruhe, *1*, Heft 4, 1896, 400; not *Bacillus putidus* Chester, Man. Determ. Bact., 1901, 237; not *Bacillus putidus* Weinberg et al., Les Microbes Anaérobies, 1937, 790.) From the stomach and intestines of birds.

Bacillus pylori Ford. (Studies from the Royal Victoria Hosp., Montreal, *1* (5), 1903, 44; also see Jour. Med. Res., *1*, 1901, 217.) From the stomach.

Bacillus pyogenes Lucet. (*Bacillus pyogenes bovis* Lucet, Ann. Inst. Past., *7*, 1893, 372; Lucet, *ibid.*, 328; not *Bacillus pyogenes* Glage, Ztschr. f. Fleish. u. Milchhyg., *13*, 1903, 166.) From bovine abscesses.

Bacillus pyogenes var. *liquefaciens* Chester. (*Bacillus pyogenes foetidus liquefaciens* Lanz, Cent. f. Bakt., *14*, 1893, 277; *Bacterium pyogenes foetidus liquefaciens* Chester, Ann. Rept. Del. Col. Agr. Exp. Sta., *9*, 1897, 92; Chester, Man. Determ. Bact., 1901, 235.) From a brain abscess after otitis media.

Bacillus pyogenes soli Bolton. (Ann. Jour. Med. Sci., June, 1892; quoted from Sternberg, Man. of Bact., 1893, 728.) From garden earth.

Bacillus pyrameis I and *II*, Paillot. (Compt. rend. Acad. Sci., Paris, *157*,

1913, 611.) From tissues and blood of the caterpillar of *Pyrameis* (*Vanessa*) *cardui*. A coccobacillus.

Bacillus radians Trevisan. (Bactérie de l'air No. 2, Babes, in Cornil and Babes, Les Bactéries, 2nd ed., 1886, 140; Trevisan, I generi e le specie delle Batteriacee, 1889, 20.) From air.

Bacillus ramificans Migula. (Bacillus No. 9, Pansini, Arch. f. path. Anat., *122*, 1890, 445; Migula, Syst. d. Bakt., *2*, 1900, 661; *Bacillus pansini* Chester, Man. Determ. Bact., 1901, 246; not *Bacillus pansinii* Migula, *loc. cit.*, 660.) From sputum.

Bacillus recuperatus Wright. (Wright, Mem. Nat. Acad. Sci., *7*, 1895, 439; *Bacterium recuperatus* Chester, Ann. Rept. Del. Col. Agr. Exp. Sta., *9*, 1897, 74.) From Schuylkill River water.

Bacillus repazii Herter. (*Bacillus moliniformis* Repazi, Compt. rend. Soc. Biol., Paris, *68*, 1910, 410; not *Bacillus moniliformis* Garnier, Arch. Méd. expér. et Anat. pathol., *19*, 1908, 785; Herter, in Just's Botan. Jahresber., *39*, 2 Abt., Heft 4, 1915, 750.) From a lung abscess.

Bacillus rhinitis atrophicans Paulsen. (Paulsen, quoted from Chester, Ann. Rept. Del. Col. Agr. Exp. Sta., *9*, 1897, 79; *Bacterium rhinitis atrophicans* Chester, *ibid.*, 141.) From nasal secretions.

Bacillus rigidus apis White. (Jour. Path. and Bact., *24*, 1921, 70.) From intestine of bee.

Bacillus rogerii Migula. (*Bacillus septicus putidus* Roger, Revue de Méd., 1891, 10; Migula, Syst. d. Bakt., *2*, 1900, 647; *Bacterium septicus putidus* Chester, Ann. Rept. Del. Col. Agr. Exp. Sta., *9*, 1897, 92; *Bacillus putidus* Chester, Man. Determ. Bact., 1901, 237; not *Bacillus putidus* Kern, Arb. bakt. Inst. Karlsruhe, *1*, Heft 4, 1896, 400; not *Bacillus putidus* Weinberg et al., Les Microbes Anaérobies, 1937, 790.) From the spinal fluid and liver in a case of cholera.

Bacillus rosaceus Migula. (*Bacillus rosaceus margarinicus* Jolles and Winkler, Ztschr. f. Hyg., *20*, 1895, 105; Migula, Syst. d. Bakt., *2*, 1900, 859.) From margarine. Red pigment.

Bacillus rosaceus metaloides Dyar. (*Bacterium rosaceus metaloides* Dowdeswell, Ann. de Micrographie, *1*, 1888–89, 310; Dyar, Ann. N. Y. Acad. Sci., *8*, 1895, 376; not *Bacillus rosaceus metalloides* Tataroff, Inaug. Diss., Dorpat, 1891, 65, see Hefferan, Cent. f. Bakt., II Abt., *8*, 1902, 689; *Bacterium rosaceum* Lehmann and Neumann, Bakt. Diag., 2 Aufl., *2*, 1899, 261.) Culture from Dr. Crookshank, London.

Bacillus roseus Migula. (*Halibacterium roseum* Fischer, Die Bakterien des Meeres, 1894, 22; Migula, Syst. d. Bakt., *2*, 1900, 860; *Bacillus roseus fischeri* Nepveux, Thèse, Fac. Pharm. Paris, 1920, 115.) From sea water. Red pigment.

Bacillus rosenthalii Migula. (Rosenthal, Inaug. Diss., Berlin, 1893, 37; Migula, Syst. d. Bakt., *2*, 1900, 656.) From the oral cavity.

Bacillus rubescens Edington. (Ann. Rept. Fish. Board for Scotland, *6*, 1887, 204.) From reddened salted codfish.

Bacillus rubescens Jordan. (Jordan, Massachusetts State Board of Health, Boston, 1890, 835; *Bacterium rubescens* Chester, Ann. Rept. Del. Col. Agr. Exp. Sta., *9*, 1897, 115.) From sewage.

Bacillus rubiginosus Catiano. (In Cohn, Beitr. z. Biol. d. Pflanzen, *7*, 1896, 538.) From the vagina. Red pigment.

Bacillus rubiformis Kern. (Arb. bakt. Inst. Karlsruhe, *1*, Heft 4, 1896, 431.) From the stomach of a bird.

Bacillus rubrofuscus (Fischer) Migula. (*Halibacterium rubrofuscum* Fischer, Die Bakterien des Meeres, 1894, 36; Migula, Syst. d. Bakt., *2*, 1900, 865.) From sea water.

Bacillus rubus (sic) Chester. (Der rother Bacillus, Lustig, Diag. d. Bakt. d. Wassers, 1893, 72; *Bacillus ruber aquatilis* Kruse, in Flügge, Die Mikroorganismen, 3 Aufl., *2*, 1896, 303; *Bacterium ruber aquatilis* Chester, Ann. Rept. Del. Col. Agr. Exp. Sta., *9*, 1897, 112; Chester,

Man. Determ. Bact., 1901, 257; *Bacillus lustigi* Chester, *ibid.*, 304.) From water.

Bacillus salmoneus Dyar. (Dyar, Ann. N. Y. Acad. Sci., *8*, 1895, 361; *Bacterium salmoneus* Chester, Ann. Rept. Del. Col. Agr. Exp. Sta., *9*, 1897, 116.) From air.

Bacillus salutarius Metchnikoff. (Metchnikoff, Maladies des hannetons du ble, Odessa (in Russian), quoted from Paillot, L'infection chez les insectes, Paris, 1933, 123.) From diseased larvae of a beetle (*Anisoplia austriaca*).

Bacillus sanguineus Schroeter. (In Cohn, Kryptog. Flora v. Schlesien, *3*, 1, 1886, 156.) From stagnant water.

Bacillus saponaceus Migula. (*Bacillus lactis saponacei* Weigman and Zirn, Cent. f. Bakt., *15*, 1894, 464; Migula, Syst. d. Bakt., *2*, 1900, 692.) From soapy milk.

Bacillus saprogenes Chester. (*Bacillus saprogenes vini VI* Kramer, Bakteriol. Landwirtsch., 1890, 139; Chester, Man. Determ. Bact., 1901, 289.) From diseased wine.

Bacillus saprogenes Trevisan. (*Bacillus saprogenes 1*, Rosenbach, Mikroorganismen bei den Wundinfectionskrankheiten des Menschen, Wiesbaden, 1884; Trevisan, I generi e le specie delle Batteriacee, 1889, 17; *Bacterium saprogenes* Chester, Ann. Rept. Del. Col. Agr. Exp. Sta., *9*, 1897, 142.) From feces.

Bacillus sarracenicolus Dyar. (Dyar, Ann. N. Y. Acad. Sci., *8*, 1895, 357; *Bacterium sorracenicolus* (sic) Chester, Ann. Rept. Del. Col. Agr. Exp. Sta., *9*, 1897, 81.) From a fresh leaf of the pitcher plant (*Sarracenia purpurea*).

Bacillus scarlatinae Jamieson and Edington. (Jamieson and Edington, Brit. Med. Jour., *1*, 1887, 1265; *Bacillus sudaminis* Trevisan, I generi e le specie delle Batteriacee, 1889, 15.) From the skin of scarlet fever patients.

Bacillus scoticus Migula. (Bacillus der Grouse-disease, Klein, Cent. f. Bakt., *6*, 1889, 36 and 593; *ibid.*, *7*, 1890, 81; Migula, Syst. d. Bakt., *2*, 1900, 768; *Bacillus tetraonis* Chester, Man. Determ. Bact., 1901, 221.) The cause of a disease of grouse (*Lagopus scoticus*) in England and Scotland.

Bacillus secundus Trevisan. (*Bacillus II*, Leube, Arch. f. path. Anat., *100*, 1885, 000; Trevisan, I generi e le specie delle Batteriacee, 1889, 16.) From urine.

Bacillus secundus fullesi Dyar. (Dyar, Ann. N. Y. Acad. Sci., *8*, 1895, 359; *Bacterium secundus fulessii* (sic) Chester, Ann. Rept. Del. Col. Agr. Exp. Sta., *9*, 1897, 82; *Bacterium secundus fullesi* Chester, *ibid.*, 143.) From air. Dyar regarded his organism as identical with *Bacillus* No. 2 of Fulles (Ztschr. f. Hyg., *10*, 1891, 250) which was from soil.

Bacillus septicaemiae lophyri Shiperovich. (Shiperovich, Protect. Plants Ukraine, 1925, 41–46; Abs. in Rev. Appl. Ent., A., *14*, 1926, 209.) From larvae of sawflies (*Diprion sertifer*).

Bacillus septicaemicus Trevisan. (Bacillus of septicemia of man, Klein, Microorganisms and Disease, 1885, 84; Trevisan, in DeToni and Trevisan, in Saccardo, Sylloge Fungorum, *8*, 1889, 945.) From blood and infected lymph glands.

Bacillus septicus hominis Mironoff. (Mironoff, Cent. f. Gynäkol., 1892, 42; *Bacterium septicus hominis* Chester, Ann. Rept. Del. Col. Agr. Exp. Sta., *9*, 1897, 143.) From a case of septic infection of the uterus. Regarded by Chester (Man. Determ. Bact., 1901, 143) as a synonym of *Pasteurella agrigena* Trevisan.

Bacillus septicus vesicae Clado. (Bull. de la Soc. anatom. de Paris, 1887, 339.) From the urine of a person suffering from cystitis.

Bacillus sericcus Zimmermann. (Bakt. unserer Trink- u. Nutzwässer, Chemnitz, *2*, 1894, 52.) From water.

Bacillus serratus Migula. (Bacillus No. 14, Pansini, Arch. f. path. Anat., *122*, 1890, 449; Migula, Syst. d. Bakt., *2*, 1900, 658.) From sputum.

Bacillus setosus Migula. (Bacillus No. XVIII, Adametz, Landwirtsch. Jahrb.,

18, 1889, 250; Migula, Syst. d. Bakt., *2*, 1900, 812.) From cheese.

Bacillus silberschmidii Chester. (Bacillus der Fleischvergiftung, Silberschmidt, Correspondenz-Blatt f. Schweizer Aerzte, 1896, No. 8; Chester, Man. Determ. Bact., 1901, 212.) From poisonous meat.

Bacillus simulans Trevisan. (Bacille de l'air *a*, Babes, in Cornil and Babes, Les Bactéries, 2nd ed., 1886, 149; Trevisan, I generi e le specie delle Batteriacee, 1889, 20.) From air.

Bacillus singularis Losski. (Inaug. Diss., Dorpat, 1893, 45.) From garden soil.

Bacillus siticulosus Kern. (Arb. bakt. Inst. Karlsruhe, *1*, Heft 4, 1896, 423.) From the stomachs and intestines of birds.

Bacillus sordidus Dyar. (Dyar, Ann. N. Y. Acad. Sci., *8*, 1895, 379; *Bacterium sordidus* Chester, Ann. Rept. Del. Col. Agr. Exp. Sta., *9*, 1897, 79.) Culture received by Dyar as *Micrococcus sordidus* from Král's laboratory.

Bacillus sordidus Kern. (Arb. Bakt. Inst. Karlsruhe, *1*, Heft 4, 1896, 396.) From the stomach of a bird.

Bacillus spermophilinus Issatchenko. (Ein aus Zieselmäusen ausgeschiedener Bacillus, Mereschkowsky, Cent. f. Bakt., *17*, 1895, 742; Issatchenko, Scripta Botanica Hort. Univ. Imp. Petropolitanae, Fasc. XV, 1897; quoted from Migula, Syst. d. Bakt., *2*, 1900, 618.) Apparently resembled *Salmonella typhimurium*. From ground squirrels (*Spermophilus musicus*).

Bacillus spirans Weiss. (Arb. bakt. Inst. Karlsruhe, *2*, Heft 3, 1902, 222.) From bean infusions.

Bacillus spumosus Zimmermann. (Bakt. unserer Trink- u. Nutzwässer, Chemnitz, *2*, 1894, 28.) From water.

Bacillus squamosus Pansini. (Arch. f. path. Anat., *122*, 1890, 448.) From sputum.

Bacillus strassmanni Trevisan. (*Bacillus albus cadaveris* Strassmann and Strecker, Ztschr. f. Medicinalbeamte, 1888; Trevisan, I generi e le specie delle Batteriacee, 1889, 17; *Bacterium albus cadaveris* Chester, Ann. Rept. Del. Col. Agr. Exp. Sta., *9*, 1897, 102; *Bacillus cadaveris* Migula, Syst. d. Bakt., *2*, 1900, 646.) From the blood of an infant.

Bacillus striatus Doyen. (*Bacillus urinae striatus* Doyen, Jour. d. connaiss. médic., 1889, 107; Doyen, *ibid.*, 108.) From urine.

Bacillus striatus albus von Besser. (Ziegler's Beiträge, *4*, 1889, 331.) Found in normal nasal mucus.

Bacillus striatus flavus von Besser. (Ziegler's Beiträge, *4*, 1889, 331; *Bacterium striatus flavus* Chester, Ann. Rept. Del. Col. Agr. Exp. Sta., *9*, 1897, 111.) From nasal mucus. Rare.

Bacillus strumitidis Migula. (*Bacillus strumitis α*, Tavel, Ueber die Aetiologie der Strumitis, Basel, 1892, 81; Migula, Syst. d. Bakt., *2*, 1900, 741.) From a case of strumitis.

Bacillus strumitis Tavel. (Tavel, 1889; see Viquerat, Ann. de Micrographie, *2*, 1889–1890, 228.) From acute catarrhal strumitis.

Bacillus subcoccoideus Migula. (*Bacillus aquatilis sulcatus III*, Weichselbaum, Das österreichische Sanitätswesen, 1889, No. 14–23; Migula, Syst. d. Bakt., *2*, 1900, 732.) From water.

Bacillus subflavus Zimmermann. (Zimmermann, Bakt. unserer Trink. u. Nutzwässer, Chemnitz, *1*, 1890, 62; *Bacterium subflavus* Chester, Ann. Rept. Del. Col. Agr. Exp. Sta., *9*, 1897, 109.) From water. According to Chester (Man. Determ. Bact., 1901, 254), *Bacillus flavescens* Pohl is identical with this species.

Bacillus subgastricus White. (U. S. Dept. Agr. Bur. Ent., Tech. Bul. 14, 1906, 23.) From intestinal contents of honey bee (*Apis mellifera*). While this does not appear to be the same as *Bacillus gastricus* Ford (see Steinhaus, Bacteria Associated Extracellularly with Insects and Ticks. Minneapolis, 1942, 85), it may have been described by some

previous author as White does not indicate that he regards it as new.

Bacillus subochraceus Dyar. (Dyar, Ann. N. Y. Acad. Sci., *8*, 1895, 358; *Bacterium subochraceus* Chester, Ann. Rept. Del. Col. Agr. Exp. Sta., *9*, 1897, 110.) From air.

Bacillus subrubiginosus Migula. (Braunroter Bacillus, Maschek, Bakt. Untersuch. d. Leitmeritzer Trinkwässer, Leitmeritz, 1887; Migula, Syst. d. Bakt., *2*, 1900, 836.) From water.

Bacillus subsulcatus Migula. (*Bacillus aquatilis sulcatus II*, Weichselbaum, Das österreichische Sanitätswesen, 1889, No. 14–23; Migula, Syst. d. Bakt., *2*, 1900, 732.) From water.

Bacillus sulcatus Chester. (*Bacillus sulcatus liquefaciens* Kruse, in Flügge, Die Mikroorganismen, 3 Aufl., *2*, 1896, 318; *Bacterium sulcatus liquefaciens* Chester, Ann. Rept. Del. Col. Agr. Exp. Sta., 9, 1897, 97; Chester, Man. Determ. Bact., 1901, 243; not *Bacillus sulcatus* Migula, Syst. d. Bakt., *2*, 1900, 731.) From water.

Bacillus sulcatus Migula. (*Bacillus aquatilis sulcatus I*, Weichselbaum, Das österreichische Sanitätswesen, 1889, No. 14–23; Migula, Syst. d. Bakt., *2*, 1900, 731.) From water.

Bacillus sulfhydrogenus Miquel. (Ann. de Micrographie, *1*, 1888–1889, 369.) From sewage.

Bacillus tardissimus DeToni and Trevisan. (*Bacillus fluidificans tardissimus* Maggiora, Giorn. Soc. ital. d'Igiene, *11*, 1889, 347; DeToni and Trevisan, in Saccardo, Sylloge Fungorum, *8*, 1889, 967.) From the skin of the human foot.

Bacillus tartricus Grimbert and Fiquet. (Jour. Pharm. et de Chim., 6e Sér., *7*, 1898, 97; Compt. rend. Soc. Biol., *49*, 1897, 962.) Decomposes d-tartrates. Probably identical with *Aerobacter cloacae* (Vaughn et al., Jour. Bact., *52*, 1946, 324).

Bacillus telmatis Trevisan. (*Bacillus saprogenes 2*, Rosenbach, Mikroorganismen bei den Wundinfectionskrankheiten des Menschen, Wiesbaden, 1884; Trevisan, I generi e le specie delle Batteriacee, 1889, 14.) From perspiration of feet.

Bacillus tenuis Doyen. (*Bacillus urinae tenuis* Doyen, Jour. d. connaiss. médic., 1889, 107; Doyen, *ibid.*, 108; not *Bacillus tenuis* Migula, Syst. d. Bakt., *2*, 1900, 587; *Bacillus tenuatus* Trevisan, in DeToni and Trevisan, in Saccardo, Sylloge Fungorum, *8*, 1889, 948.) From urine.

Bacillus tenuis apis White. (Jour. Path. and Bact., *24*, 1921, 72.) From intestine of bee.

Bacillus terrigenus Frank. (Berichte deutsch. botan. Gesellsch., *4*, 1886, 000.) From soil.

Bacillus thermophilus Miquel. (Miquel, Ann. de Microgr., *1*, 1888–1889, 6; not *Bacillus thermophilus* Chester, Man. Determ. Bact., 1901, 265; not *Bacillus thermophilus* Bergey et al., Manual, 1st ed., 1923, 315.) From water, sewage, soil, etc.

Bacillus theta Dyar. (Ann. N. Y. Acad. Sci., *8*, 1895, 375; *Bacterium theta* Chester, Ann. Rept. Del. Col. Agr. Exp. Sta., *9*, 1897, 144.) From air.

Bacillus tingens Eckstein. (Ztschr. f. Forst- u. Jagdwesen, *26*, 1894, 10.) From dead larvae of *Orgyia pudibunda*.

Bacillus toluolicum Tausson. (Planta, *7*, 1929, 735.) From soil. Oxidizes toluene.

Bacillus toxigenus Chester. (Bacillus of ice cream poisoning, Vaughn and Perkins, Arch. f. Hyg., *27*, 1896, 308; Chester, Man. Determ. Bact., 1901, 208.) From poisonous ice cream.

Bacillus trambustii Kruse. (Trambusti and Galeotti, Cent. f. Bakt., *11*, 1892, 717; Kruse, in Flügge, Die Mikroorganismen, 3 Aufl., *2*, 1896, 319; *Bacterium trambusti* Chester, Ann. Rept. Del. Col. Agr. Exp. Sta., *9*, 1897, 97.) From water.

Bacillus tremaergasius Trevisan. (Bacille du mucus intestinal normal *d*, Babes, in Cornil and Babes, Les Bactéries, 2nd ed., 1886, 153; Trevisan, I generi e le specie delle Batteriacee, 1889, 15.) From normal intestinal mucus.

Bacillus trimethylamin Beijerinck. (Bot. Zeitung, *46*, 1888, 726.)

Bacillus truttae Mersch. (Quoted from Lehmann and Neumann, Bakt. Diag., 7 Aufl., *2*, 1927, 481.) Closely related to *Bacterium salmonicida* Lehmann and Neumann.

Bacillus tumidus Chester. (Anaerobe Bacillus I, Sanfelice, Ztschr. f. Hyg., *14*, 1893, 268; Chester, Man. Determ. Bact., 1901, 265.) From putrefying flesh. Strict anaerobe.

Bacillus uffreduzzii Trevisan. (Batterio della setticemia salivare nei conigli, Bordoni-Uffreduzzi and Di-Mattei, Arch. per le scienze med., *10*, 1886; Trevisan, see DeToni and Trevisan, in Saccardo, Sylloge Fungorum, *8*, 1889, 951.) From normal human saliva.

Bacillus ulna Cohn. (Beitr. z. Biol. d. Pflanz., *1*, Heft 2, 1872, 177.) From water, air, etc.

Bacillus umbilicatus Zimmermann. (Bakt. unserer Trink- u. Nutzwässer, Chemnitz, *2*, 1894, 6.) From water.

Bacillus urinae Migula. (Ein Harnbacterium, Karplus, Arch. f. path. Anat., *131*, 1893, 211; Migula, Syst. d. Bakt., *2*, 1900, 739.) From urine.

Bacillus utpadeli Trevisan. (Bacillus aus Zwischendeckenfüllung, Utpadel, Arch. f. Hyg., *6*, 1887, 359; Trevisan, I generi e le specie delle Batteriacee, 1889, 15.) From the intestine.

Bacillus vacuolatus Dyar. (Dyar, Ann. N. Y. Acad. Sci., *8*, 1895, 357; *Bacterium vacuolatus* Chester, Ann. Rept. Del. Col. Agr. Exp. Sta., *9*, 1897, 81.) From a trap of the carnivorous water plant, *Utricularia vulgaris*.

Bacillus vegetus Kern. (Arb. bakt. Inst. Karlsruhe, *1*, Heft 4, 1896, 399.) From the stomach and intestines of birds.

Bacillus velox Kern. (Arb. bakt. Inst. Karlsruhe, *1*, Heft 4, 1896, 405.) From the stomach and intestines of birds.

Bacillus venenosus brevis Vaughan. (Amer. Jour. Med. Sci., *104*, 1892, 192; *Bacterium venenosus* and *Bacterium venenosus brevis* Chester, Ann. Rept. Del. Col. Agr. Exp. Sta., *9*, 1897, 76.) From water.

Bacillus venenosus Chester. (*Bacillus venenosus invisibilis* Vaughan, Amer. Jour. Med. Sci., *104*, 1892, 192; *Bacterium venenosus invisibilis* Chester, Ann. Rept. Del. Col. Agr. Exp. Sta., *9*, 1897, 76; Chester, Man. Determ. Bact., 1901, 224; not *Bacillus venenosus* Vaughan, Amer. Jour. Med. Sci., *104*, 1892, 191.) From water.

Bacillus venenosus liquefaciens Vaughan. (Amer. Jour. Med. Sci., *104*, 1892, 193.) From water.

Bacillus ventricosus Weiss. (Weiss, Arb. bakt. Inst. Karlsruhe, *2*, Heft 3, 1902, 233; not *Bacillus ventricosus* Bredemann and Heigener, Cent. f. Bakt., II Abt., *93*, 1935, 102.) From vegetable infusions.

Bacillus ventriculi Raczynski. (Diss. milit. medic. Acad. Petropolitanae Ruteniae, 1888; abst. in Cent. f. Bakt., *6*, 1889, 113.) From the stomach of a dog.

Bacillus vermiculosus Zimmermann. (Zimmermann, Bakt. unserer Trink- u. Nutzwässer, Chemnitz, *1*, 1890, 40; *Bacterium vermiculosus* Chester, Ann. Rept. Del. Col. Agr. Exp. Sta., *9*, 1897, 99.) From water.

Bacillus versatilis DeToni and Trevisan. (*Bacillus A*, Maggiora, Giorn. Soc. ital. d'Igiene, *11*, 1889, 339; DeToni and Trevisan, in Saccardo, Sylloge Fungorum, *8*, 1889, 968.) From the skin of the human foot and from air.

Bacillus vesiculiferus Migula. (*Bacillus strumitis β*, Tavel, Ueber die Aetiologie der Strumitis, 1892, 110; Migula, Syst. d. Bakt., *2*, 1900, 741.) From a case of strumitis.

Bacillus vialis Hansgirg. (Oesterr. bot. Ztschr., 1888, 6.) From roadside soil from near Prague.

Bacillus viator Trevisan. (Bacille de l'air *e*, Babes, in Cornil and Babes, Les Bactéries, 2nd ed., 1886, 150; Trevisan, I generi e le specie delle Batteriacee, 1889, 20.) From air.

Bacillus villosus Migula. (*Bacillus aquatilis villosus* Tataroff, Inaug. Diss.,

Dorpat, 1891, 47; Migula, Syst. d. Bakt., *2*, 1900, 828; not *Bacillus villosus* Keck, Inaug. Diss., Dorpat, 1890, 47.) From water.

Bacillus vinicola Migula. (*Bacillus saprogenes vini II*, Kramer, Die Bakterien in ihren Beziehungen zur Landwirtschaft, *2*, 1892, 136; Migula, Syst. d. Bakt., *2*, 1900, 685.) From wine.

Bacillus viniperda Migula. (*Bacillus saprogenes vini I*, Kramer, Die Bakterien in ihren Beziehungen zur Landwirtschaft, *2*, 1892, 135; Migula, Syst. d. Bakt., *2*, 1900, 684.) From wine.

Bacillus virens van Tieghem. (Bull. Soc. bot. France, *27*, 1880, 175.) From aquatic plants.

Bacillus viridans Zimmermann. (Bakt. unserer Trink. u. Nutzwässer, Chemnitz, *2*, 1894, 22.) From water.

Bacillus viridescens non-liquefaciens Ravenel. (Ravenel, Mem. Nat. Acad. Sci., *8*, 1896, 14; *Bacterium viridescens non-liquefaciens* Chester, Ann. Rept. Del. Col. Agr. Exp. Sta., *9*, 1897, 72 and 123.) From soil.

Bacillus vulpinus von Iterson. (Cent. f. Bakt., II Abt., *12*, 1904, 111.) From fresh garden soil, canal water.

Bacillus wardii Chester. (Gas- and taint-producing bacillus in cheese curd, Moore and Ward, Cornell Univ. Agr. Expt. Sta., Bull. 158, 1899, 221–227; Chester, Man. Determ. Bact., 1901, 206.) From tainted, gassy cheese curd and from milk drawn directly from the udder. Presumably this was a coliform organism.

Bacillus weckeri Trevisan. (Bacillus der Jequirity-Ophthalmie, de Wecker, 1882; see Flügge, Die Mikroorganismen, 2 Aufl., 1886, 279; Trevisan, I generi e le specie delle Batteriacee, 1889, 17.) From infusions of jequirity seed (*Abri precatorii*).

Bacillus wesenbergii Chester. (Bacillus der Fleischvergiftung, Wesenberg, Ztschr. f. Hyg., *28*, 1898, 484; Chester, Man. Determ. Bact., 1901, 247; not *Bacillus wesenberg* Castellani.) From meat which caused a meat poisoning outbreak. Closely related to *Proteus vulgaris* Hauser.

Bacillus wichmanni Trevisan. (Goldgelber Wasserbacillus, Adametz and Wichmann, Mitth. Oest. Vers. Stat. f. Brauerei u. Mälz., *1*, 1888, 49; Trevisan, I generi e le specie delle Batteriacee, 1889, 19; *Bacillus chryseus* Migula, Syst. d. Bakt., *2*, 1900, 833.) From water.

Bacillus zeta Dyar. (Dyar, Ann. N. Y. Acad. Sci., *8*, 1895, 369; *Bacterium zeta* Chester, Ann. Rept. Del. Col. Agr. Exp. Sta., *9*, 1897, 114.) From air.

Bacillus zonatus Migula. (Bacillus No. 15, Pansini, Arch. f. path. Anat., *122*, 1890, 450; Migula, Syst. d. Bakt., *2*, 1900, 658.) From sputum.

Bacillus zörkendörferi Migula. (*Bacillus oogenes hydrosulfureus γ*, Zörkendörfer, Arch. f. Hyg., *16*, 1893, 385; Migula, Syst. d. Bakt., *2*, 1900, 696.) From hens' eggs.

Bacillus zymoseus (Leube) Trevisan. (*Coccobacillus zymogenes* Leube, Arch. f. path. Anat., 1885; Trevisan, I generi e le specie delle Batteriacee, 1889, 16.) From fermenting infusions.

Bacterium acidi propionici Weigmann. (Weigmann, quoted from Pribram, Klassifikation der Schizomyceten, Leipzig und Wien, 1933, 76; *Plocamobacterium acidi propionici* Pribram, *idem*.)

Bacterium aeris Migula. (*Bacillus aeris minutissimus* Kruse, in Flügge, Die Mikroorganismen, 3 Aufl., *2*, 1896, 441; *Bacterium aeris minutissimus* Chester, Ann. Rept. Del. Col. Agr. Exp. Sta., *9*, 1897, 109; Migula, Syst. d. Bakt., *2*, 1900, 445; *Bacterium aeris-minutissimum* Chester, Man. Determ. Bact., 1901, 168.) From air.

Bacterium aerogenes I and *II* Miller. (Miller, Deutsche med. Wochnschr., *12*, 1886, 119; see Miller, Die Mikroorganismen der Mundhöhle, Leipzig, 1889, 261 and 262; not *Bacterium aerogenes* Chester, Ann. Rept. Del. Col. Agr. Exp. Sta., *9*, 1897, 53; *Bacillus millerianus* DeToni and Trevisan, in Saccardo, Sylloge Fungorum, *8*, 1889, 952.) From the digestive tract of man.

Bacterium agreste Löhnis. (Löhnis, Cent. f. Bakt., I Abt., Orig., *40*, 1906, 177; *Bacillus agrestis* de Rossi, Microbiol. agraria e technica, Torino, 1927, 828; not *Bacillus agrestis* Werner, Cent. f. Bakt., II Abt., *87*, 1933, 468.) From soil.

Bacterium agrigenum (Trevisan) Migula. (*Bacillus septicus agrigenus* Flügge, Die Mikroorganismen, 2 Aufl., 1886, 257; *Pasteurella agrigena* Trevisan, I generi e le specie delle Batteriacee, 1889, 21; *Bacterium septicus agrigenus* Chester, Ann. Rept. Del. Col. Agr. Exp. Sta., *9*, 1897, 85; Migula, Syst. d. Bakt., *2*, 1900, 372; *Bacterium septicum* Chester, Man. Determ. Bact., 1901, 143.) From soil.

Bacterium album Migula. (Weisser Bacillus, Tataroff, Inaug. Diss., Dorpat, 1891, 35; Migula, Syst. d. Bakt., *2*, 1900, 419.) From water.

Bacterium algeriense Migula. (Gayon and Dubourg, Ann. Inst. Past., *8*, 1894, 108; Migula, Syst. d. Bakt., *2*, 1900, 513.) Isolated in Algiers from wine where it causes a mannitol fermentation.

Bacterium aliphaticum Tausz and Peter. (Cent. f. Bakt., II Abt., *49*, 1919, 505.) From garden soil.

Bacterium aliphaticum liquefaciens Tausz and Peter. (Cent. f. Bakt., II Abt., *49*, 1919, 505.) From garden soil.

Bacterium allantoides (Klein) Chester. (*Bacillus allantoides* Klein, Cent. f. Bakt., *6*, 1889, 383; Chester, Ann. Rept. Del. Col. Agr. Exp. Sta., *9*, 1897, 103.) Isolated as a culture contamination.

Bacterium alutaceum Migula. (Goldgelber chagrinierter Bacillus, Tataroff, Inaug. Diss., Dorpat, 1891, 62; Migula, Syst. d. Bakt., *2*, 1900, 464.) From water.

Bacterium ambiguum Chester. (Chester, Ann. Rept. Del. Col. Agr. Exp. Sta., *11*, 1900, 59; not *Bacterium ambiguus* Chester, *ibid.*, *9*, 1897, 71; not *Bacterium ambiguum* Levine, Abst. Bact., *4*, 1920, 15.) From soil.

Bacterium amforeti Issatchenko. (Recherches sur les microbes de l'Océan Glacial Arctique (in Russian), Petrograd, 1914, 237.) From sea water.

Bacterium anaerobium Migula. (Fuchs, Inaug. Diss., Greifswald, 1890; Migula, Syst. d. Bakt., *2*, 1900, 388.) Obligate anaerobe. Pyogenic. Possibly a spore-former.

Bacterium anguillarum (Canestrini) Migula. (*Bacillus anguillarum* Canestrini, Atti d. R. Instituto Veneto di Scienze, Ser. 7, 1892–93; Migula, Syst. d. Bakt., *2*, 1900, 442.) From diseased eels in the valleys of Comacchio.

Bacterium angustum Migula. (Lembke, Arch. f. Hyg., *26*, 1896, 305; Migula, Syst. d. Bakt., *2*, 1900, 474.) From feces.

Bacterium aphthosum (Kruse) Chester. (Bacillus der Mundseuche des Menschen, Siegel, Deutsch. med. Wochnschr., 1891, No. 49, 1328; *Bacillus aphthosus* Kruse, in Flügge, Die Mikroorganismen, 3 Aufl., *2*, 1896, 427; Chester, Ann. Rept. Del. Col. Agr. Exp. Sta., *9*, 1897, 85.) From the liver and kidneys of cattle affected with foot and mouth disease.

Bacterium apis No. 1, No. 2 and No. 3, Metalnikov and Kostritsky. (Compt. rend. Soc. Biol., Paris, *114*, 1933, 1291.) From diseased bees (*Apis mellifera.*)

Bacterium aquatile aurantiacum von Rigler. (Hyg. Rund., *12*, 1902, 480.) From bottled mineral waters.

Bacterium aquatile citreum von Rigler. (Hyg. Rund., *12*, 1902, 481.) From bottled mineral waters.

Bacterium aquatile debile von Rigler. (Hyg. Rund., *12*, 1902, 481.) From bottled mineral waters.

Bacterium aquatile flavum von Rigler. (Hyg. Rund., *12*, 1902, 480.) From bottled mineral waters.

Bacterium aquatile luteum von Rigler. (Hyg. Rund., *12*, 1902, 480.) From bottled mineral waters.

Bacterium arborescens non liquefaciens von Rigler. (Hyg. Rund., *12*, 1902, 479; not *Bacterium arborescens non-liquefaciens* Chester, Ann. Rept. Del. Col. Agr. Exp. Sta., *9*, 1897, 103.) From bottled mineral waters.

Bacterium arcticum Issatchenko. (Re-

cherches sur les microbes de l'Océan Glacial Arctique (in Russian). Petrograd, 1914, 148.) From sea water.

Bacterium arthritidis Migula. (Schüller, Berliner klin. Wochnschr., 1893, No. 36; *Bacillus arthritidis chronicae* Kruse, in Flügge, Die Mikroorganismen, 3 Aufl., *2*, 1896, 287; Migula, Syst. d. Bakt., *2*, 1900, 443.) From a case of chronic arthritis.

Bacterium asporiferum Migula. (Flügge, Ztschr. f. Hyg., *17*, 1894, 290; Anaërobier No. II, Kruse, in Flügge, Die Mikroorganismen, 3 Aufl., *2*, 1896, 251; Migula, Syst. d. Bakt., *2*, 1900, 446.) From milk.

Bacterium aurantii (Viron) Migula. (*Bacillus aurantii* Viron, Compt. rend. Acad. Sci., Paris, 114, 1892, 179; Migula, Syst. d. Bakt., *2*, 1900, 512.)

Bacterium aurantium-roseum Honing. (Honing, Cent. f. Bakt., II Abt., *37*, 1913, 373; *Plocamobacterium aurantium* Pribram, Klassifikation der Schizomyceten, Leipzig und Wien, 1933, 77.) From fermenting tobacco.

Bacterium aurescens (Frankland and Frankland) Migula. (*Bacillus aurescens* Frankland and Frankland, Philos. Trans. Royal Soc. of London, *178*, 1887, B, 271; not *Bacillus aurescens* Ravenel, Mem. Nat. Acad. Sci., *8*, 1896, 8; Migula, Syst. d. Bakt., *2*, 1900, 466.) From air.

Bacterium aureum (Frankland and Frankland) Migula. (*Bacillus aureus* Frankland and Frankland, Philos. Trans. Royal Soc. of London, *178*, 1887, B, 272; Migula, Syst. d. Bakt., *2*, 1900, 480.) From air.

Bacterium aureum (Adametz) Chester. (*Bacillus aureus* Adametz, quoted from Sternberg, Man. of Bact., 1893, 621; not *Bacillus aureus* Frankland and Frankland, Philos. Trans. Roy. Soc. London, *178*, 1887, B, 272; not *Bacillus aureus* Pansini, Arch. f. path. Anat., *122*, 1890, 436; *Bacillus aureo-flavus* Kruse, in Flügge, Die Mikroorganismen, 3 Aufl., *2*, 1896, 310; *Bacterium aureo flavus* Chester, Ann. Rept. Del. Col. Agr. Exp. Sta., *9*, 1897, 109; Chester, *ibid.*, 129; not *Bacterium aureum* Migula, Syst. d. Bakt., *2*, 1900, 480; *Bacillus flavus* Chester, Man. Determ. Bact., 1901, 255; not *Bacillus flavus* Fuhrmann, Cent. f. Bakt., II Abt., *19*, 1907, 117; not *Bacillus flavus* Bergey et al., Manual, 1st ed., 1923, 286.) From water (Adametz); from the skin in cases of eczema (Tommasoli, Monats. f. prakt. Dermatol., *9*.)

Bacterium avium Chester. (Bacillus of roup in fowls, Moore, U. S. Dept. Agr. Bur. Animal Industry, Bull. 8, 1895; Chester, Man. Determ. Bact., 1901, 138.) From exudate of fowls in roup or diphtheria.

Bacterium babesii Migula. (*Bacillus septicus acuminatus* Babes, Bakteriologische Untersuchungen der septischen Prozesse des Kindesalters, Leipzig, 1889; see Eisenberg, Bakt. Diag., 3 Aufl., 1891, 327; *Bacterium septicus acuminatus* Chester, Ann. Rept. Del. Col. Agr. Exp. Sta., *9*, 1897, 66; Migula, Syst. d. Bakt., *2*, 1900, 507; *Bacterium acuminatum* Chester, Man. Determ. Bact., 1901, 119.) From blood and organs of a new-born infant with septicemia.

Bacterium balbianii Billet. (Billet, Compt. rend. Acad. Sci., Paris, *107*, 1888, 423; also in Bull. Sci. de la France et de la Belgique, *21*, 1890, 108; *Bacillus balbianii* Trevisan, I generi e le specie delle Batteriacee, 1889, 17.) From sea water.

Bacterium barentsianum Issatchenko. (Recherches sur les microbes de l'Océan Glacial Arctique (in Russian). Petrograd, 1914, 155.) From sea water.

Bacterium beijerincki Issatchenko. (Recherches sur les microbes de l'Océan Glacial Arctique (in Russian). Petrograd, 1914, 157.) From sea water.

Bacterium benzoli a and *b* Wagner. (Ztschr. f. Garungphysiol., *4*, 1914, 289.) From soil. Utilize benzene and certain benzene derivatives.

Bacterium besseri Migula. (Besser, Cent. f. Bakt., *13*, 1893, 590; Migula, Syst. d. Bakt., *2*, 1900, 508.) From smallpox.

Bacterium betae viscosum Panek. (Bull. Acad. Sci. Cracovie, *1*, 1905, 5.)

From fermenting beets. Reported to liquefy agar-gelatin (Biernacki, Cent. f. Bakt., *29*, 1911, 166). Stanier (Jour. Bact., *42*, 1941, 548) thinks this was a heterofermentative *Lactobacillus*.

Bacterium bossonis Chester. (Bacillus über eine neue Infektionskrank. des Rindviehs, Bosso, Cent. f. Bakt., *22*, 1897, 537 and *23*, 1898, 318; Chester, Man. Determ. Bact., 1901, 153.) Associated with an infectious disease of cattle.

Bacterium boutrouxii (Trevisan) De-Toni and Trevisan. (Micrococcus capable d'acétifier l'alcohol, Boutroux, Ann. Inst. Past., *2*, 1888, 209; *Bacillus boutrouxii* Trevisan, I generi e le specie delle Batteriacee, 1889, 16; DeToni and Trevisan, in Saccardo, Sylloge Fungorum, *8*, 1889, 1021.) From alcoholic infusions.

Bacterium bovis Migula. (*Pneumobacillus liquefaciens bovis* Arloing, Compt. rend. Acad. Sci., Paris, *99*, 18—, 109 and 116; *Bacillus pneumonicus liquefaciens* Kruse, in Flügge, Die Mikroorganismen, 3 Aufl., *2*, 1896, 288; *Bacterium pneumonicus liquefaciens* Chester, Ann. Rept. Del. Col. Agr. Exp. Sta., *9*, 1897, 99; Migula, Syst. d. Bakt., *2*, 1900, 442; *Bacterium pneumonicum* Chester, Man. Determ. Bact., 1901, 158.) From the exudate of lung plague in cattle. A Gram-positive coccus-like bacterium.

Bacterium brassicae Conrad. (*Bacterium brassicae acidae* Lehmann and Conrad, in Lehmann and Neumann, Bakt. Diag., 1 Aufl., *2*, 1896, 232; Conrad, Arch. f. Hyg., *29*, 1897, 82; not *Bacterium brassicae* Wehmer, Cent. f. Bakt., II Abt., *10*, 1903, 628; not *Bacterium brassicae* Migula, Syst. d. Bakt., *2*, 1900, 296 (*Bacillus brassicae* Pommer, Mitt. botan. Inst. Graz, *1*, 1886, 95); *Bacillus brassicae* Migula, *loc. cit.*, 737.) From sauerkraut.

Bacterium breitfussi Issatchenko. (Recherches sur les microbes de l'Océan Glacial Arctique (in Russian). Petrograd, 1914, 152.) From sea water.

Bacterium brevissimum Weiss. (Arb. bakt. Inst. Karlsruhe, *2*, Heft 3, 1902, 227.) From vegetable infusions.

Bacterium brunneoflavum (Dyar) Chester. (*Bacillus brunneoflavus* Dyar, Ann. N. Y. Acad. Sci., *8*, 1895, 362; Chester, Ann. Rept. Del. Col. Agr. Exp. Sta., *9*, 1897, 112.) Culture received from Kràl's laboratory as *Micrococcus brunneus*.

Bacterium bullosum Migula. (Bacillus No. 18, Pansini, Arch. f. pathol. Anat. u. Physiol., *122*, 1890, 451; Migula, Syst. d. Bakt., *2*, 1900, 415.) From feces.

Bacterium cadaveris (Sternberg) Chester. (*Bacillus cadaveris* Sternberg, Man. of Bact., 1893, 492; Chester, Ann. Rept. Del. Col. Agr. Exp. Sta., *9*, 1897, 126.) From liver and kidneys of yellow fever cadavers. Anaerobe.

Bacterium canalis Migula. (Kapseltragender Kanalbacillus, Mori, Ztschr. f. Hyg., *4*, 1888, 52; *Bacillus canalis capsulatus* Sternberg, Man. of Bact., 1893, 476; *Bacterium canalis capsulatus* Chester, Ann. Rept. Del. Col. Agr. Exp. Sta., *9*, 1897, 130; Migula, Syst. d. Bakt., *2*, 1900, 351.) From sewage.

Bacterium canalis parvum (Sternberg) Chester. (*Bacillus canalis parvus* Sternberg, Man. of Bact., 1893, 476; Chester, Ann. Rept. Del. Col. Agr. Exp. Sta., *9*, 1897, 130.) Obtained by Mori (1888) from sewage.

Bacterium carneum (Kruse) Chester. (Fleischfarbiger Bacillus, Tils, Ztschr. f. Hyg., *9*, 1890, 294; *Bacillus carnicolor* Frankland and Frankland, Microorganisms of Water, 1894, 477; *Bacillus carneus* Kruse, in Flügge, Die Mikroorganismen, 3 Aufl., *2*, 1896, 304; Chester, Ann. Rept. Del. Col. Agr. Exp. Sta., *9*, 1897, 113.) From water.

Bacterium carnosum Kern. (Arb. bakt. Inst. Karlsruhe, *1*, Heft 4, 1896, 448.) From the intestines of birds.

Bacterium cartilagineum (Olsen-Sopp) Buchanan and Hammer. (*Bacillus cartilagineus* Olsen-Sopp, Cent. f. Bakt., II Abt., *33*, 1912, 49; Buchanan and Hammer, Iowa Sta. Agr. Exp. Sta., Res. Bull. 22, 1915, 271.) From slimy or ropy sour milk called false taette.

Bacterium caseicola Migula. (Bacillus No. XII, Adametz, Landw. Jahrb., *18*, 1889, 245; Migula, Syst. d. Bakt., *2*, 1900, 475.) From cheese.

Bacterium castellum Henrici. (Arb. bakt. Inst. Karlsruhe, *1*, Heft 1, 1894, 38.) From cheese.

Bacterium catenula Dujardin. (Dujardin, Hist. natur. des zooph., 1841; *Bacillus catenula* Trevisan, I generi e le specie delle Batteriacee, 1889, 18; not *Bacillus catenula* Migula, Syst. d. Bakt., *2*, 1900, 588.) From rice paddies and swamps.

Bacterium cavatum Kern. (Arb. bakt. Inst. Karlsruhe, *1*, Heft 4, 1896, 449.) From the intestines of birds.

Bacterium cavernae Migula. (*Bacillus cavernae minutissimus* Kruse, in Flügge, Die Mikroorganismen, 3 Aufl., *2*, 1896, 440; Pfeiffer und Beck, Deutsch. med. Wochnschr., 1892, No. 21; Migula, Syst. d. Bakt., *2*, 1900, 509.) From human tuberculosis.

Bacterium caviae fortuitum (Sternberg) Chester. (*Bacillus caviae fortuitus* Sternberg, Man. of Bact., 1893, 650; Chester, Ann. Rept. Del. Col. Agr. Exp. Sta., *9*, 1897, 74.) From the liver of a yellow fever cadaver.

Bacterium cavicida havaniensis (Sternberg) Chester. (*Bacillus cavicida havaniensis* Sternberg, Man. of Bact., 1893, 425; Chester, Ann. Rept. Del. Col. Agr. Exp. Sta., *9*, 1897, 74.) From the intestine of a yellow fever cadaver.

Bacterium centricum Migula. (Huber, Armin, Arch. f. pathol. Anat. u. Physiol., *134*, 1893, 216; Migula, Syst. d. Bakt., *2*, 1900, 390; not *Bacterium concentricum*, a typographical error, see Migula, *ibid.*, page v.) From a case of cystitis.

Bacterium cerinum Henrici. (Arb. bakt. Inst. Karlsruhe, *1*, Heft 1, 1894, 50.) From cheese.

Bacterium chlorinum Engelmann. (Bot. Zeitung, 1882, 324.) Green pigment.

Bacterium chologenes (Kruse) Chester. (Colonbacillus, Stern, Deutsche med. Wochnschr., 1893, 613; *Bacillus chologenes* Kruse, in Flügge, Die Mikroorganismen, 3 Aufl., *2*, 1896, 374; Chester, Ann. Rept. Del. Col. Agr. Exp. Sta., *9*, 1897, 69.) From a case of purulent meningitis.

Bacterium chryseum Migula. (Bacillus nova species II, Freund, Inaug. Diss., Erlangen, 1893, 37; Migula, Syst. d. Bakt., *2*, 1900, 477.) Chromogenic bacterium from the mouth cavity.

Bacterium chrysogloea Zopf. (Zopf, in Overbeck, Nova Acta d. kais. Leop.-Carol. Akad. d. Naturf., *55*, 1891, No. 7; *Bacillus chrysogloia* (sic) Zimmermann, Bakt. unserer Trink- u. Nutzwässer, *2*, 1894, 12.) From water.

Bacterium citreum (Frankland and Frankland) Migula. (*Bacillus citreus* Frankland and Frankland, Philos. Trans. Royal Soc. of London, *178*, 1887, B, 272; Migula, Syst. d. Bakt., *2*, 1900, 459.) From air.

Bacterium coli apium Serbinow. (Jour. Microbiol. Petrograd., *2*, 1915, 19.) From honey bees (*Apis mellifera*).

Bacterium coli similis (Sternberg) Chester. (*Bacillus coli similis* Sternberg, Man. of Bact., 1893, 650; Chester, Ann. Rept. Del. Col. Agr. Exp. Sta., *9*, 1897, 132.) From a human liver.

Bacterium colloideum Migula. (*Bacterium butyri colloideum* Lafar, Arch. f. Hyg., *13*, 1891, 17; Migula, Syst. d. Bakt., *2*, 1900, 409.) From butter.

Bacterium comes Bersteyn. (Arb. bakt. Inst. Karlsruhe, *3*, 1903, 93.) From soil.

Bacterium compactum (Kruse) Migula. (*Bacillus compactus* Kruse, in Flügge, Die Mikroorganismen, 3 Aufl., *2*, 1896, 353; Migula, Syst. d. Bakt., *2*, 1900, 438.) From air.

Bacterium concentricum Kern. (Arb. bakt. Inst. Karlsruhe, *1*, Heft 4, 1896, 437.) From the intestines of birds.

Bacterium conjunctivitidis (Kruse) Migula. (Koch, Berichte aus Aegypten an den preuss. Staatsminister des Innern; see Arb. a. d. kaiserl. Gesundheitsamte, *3*, 1887; Kartulis, Cent. f. Bakt., *1*, 1887, 289; *Bacillus aegyptius*

Trevisan, I generi e le specie delle Batteriacee, 1889, 13; *Bacillus conjunctivitidis* Kruse, in Flügge, Die Mikroorganismen, 3 Aufl., *2*, 1896, 440; *Bacterium conjunctivitis* Chester, Ann. Rept. Del. Col. Agr. Exp. Sta., *9*, 1897, 67; Migula, Syst. d. Bakt., *2*, 1900, 509; not *Bacterium conjunctivitidis* Chester, Man. Determ. Bact., 1901, 120; *Bacterium aegyptium* Chester, *ibid.*, 121.) Associated with conjunctival catarrh in Egypt.

Bacterium corticale (Haenlein) Migula. (*Bacillus corticalis* Haenlein, Deutsch. Gerberzeitung, 1894, No. 18–34; Migula, Syst. d. Bakt., *2*, 1900, 449.) Found on pine bark; in acid dyeing-liquor.

Bacterium crenatum Weiss. (Arb. bakt. Inst. Karlsruhe, *2*, Heft 3, 1902, 221.) From fermenting malt.

Bacterium cristalliferum Gicklhorn. (Cent. f. Bakt., II Abt., *50*, 1920, 420.) A sulfur bacterium from soil. See Manual, 5th ed., 1939, 86 for a description of this organism.

Bacterium cuticularis (Tils) Chester. (*Bacillus cuticularis* Tils, Ztschr. f. Hyg., *9*, 1890, 293; Chester, Ann. Rept. Del. Col. Agr. Exp. Sta., *9*, 1897, 105.) From water.

Bacterium debile Berstyn. (Arb. bakt. Inst. Karlsruhe, *3*, 1903, 96.) From soil.

Bacterium delendae-muscae Roubaud and Descazeaux. (Compt. rend. Acad. Sci., Paris, *177*, 1923, 716.) From fly larvae (*Stomoxys calcitrans* and *Musca domestica*).

Bacterium deliense Honing. (Cent. f. Bakt., II Abt., *37*, 1913, 377.) From tobacco plants in Sumatra.

Bacterium diatrypeticum Migula. (*Bacillus diatrypeticus casei* Baumann, Landwirtsch. Versuchsstationen, *42*, 1893, 181; Migula, Syst. d. Bakt., *2*, 1900, 404.) From cheese.

Bacterium enchelys Ehrenberg. (Ehrenberg, Abhandl. d. Akad. d. Wissensch. zu Berlin, 1830, 61; *Bacillus enchelys* Trevisan, I generi e le specie delle Batteriacee, 1889, 18.) From water.

Bacterium endocarditidis Migula. (*Bacillus endocarditidis capsulatus* Weichselbaum, Beitr. z. pathol. Anat. u. z. allgem. Pathol., *4*, 1887, 197; Migula, Syst. d. Bakt., *2*, 1900, 359.) Found in the aorta, the left ventricle, the spleen and kidneys of cadavers.

Bacterium endometritidis (Kruse) Chester. (*Bacillus endometritidis* Kruse, in Flügge, Die Mikroorganismen, 3 Aufl., *2*, 1896, 432; Chester, Ann. Rept. Del. Col. Agr. Exp. Sta., *9*, 1897, 88.) From a liver abscess.

Bacterium endometritis canis Meyer. (Meyer, quoted from Pribram, Klassifikation der Schizomyceten, Leipzig und Wien, 1933, 77; *Plocamobacterium endometritis* Pribram, *idem.*) From a case of endometritis in a dog.

Bacterium enterocoliticum Schleifstein and Coleman. (A motile, Gram-negative bacillus, Schleifstein and Coleman, N. Y. State Jour. Med., *39*, 1939, 1749; Ann. Rept. Div. Lab. and Res., N. Y. State Dept. Health for 1943, 56.) From lesions about the face, from an ulcer in the intestine and from the intestinal contents. Resembles *Bacillus lignieri* and *Pasteurella pseudotuberculosis*.

Bacterium erythromyxa (Zopf) Migula. (*Micrococcus* (*Staphylococcus*) *erythromyxa* Zopf, Ber. d. deutschen bot. Gesellsch., 1891, 22; *Rhodococcus erythromyxa* Zopf, *loc. cit.*; Migula, Syst. d. Bakt., *2*, 1900, 487; *Bacillus erythromyxa* Matzuschita, Bakt. Diag., 1902, 389.) Frequently listed as a *Micrococcus*.

Bacterium exanthematicum (Kruse) Chester. (Bacille, Babes and Oprescu, Ann. Inst. Past., *5*, 1891, 273; *Bacillus exanthematicus* Kruse, in Flügge, Die Mikroorganismen, 3 Aufl., *2*, 1896, 426; Chester, Ann. Rept. Del. Col. Agr. Exp. Sta., *9*, 1897, 87.) From a case of hemorrhagic septicemia.

Bacterium fausseki Issatchenko. (Recherches sur les microbes de l'Océan Glacial Arctique (in Russian). Petrograd, 1914, 157.) From sea water.

Bacterium ferophilum (sic) Migula.

(Die ferrophilen Bakterien, Marpmann, Cent. f. Bakt., II Abt., *4*, 1898, 21; Migula, Syst. d. Bakt., *2*, 1900, 455 and 1058.) Isolated during studies on black discoloration of cheese.

Bacterium finitimum Chester. (*Bacillus finitimus ruber* Dyar, Ann. N. Y. Acad. Sci., *8*, 1895, 361; *Bacterium finitimus ruber* Chester, Ann. Rept. Del. Col. Agr. Exp. Sta., *9*, 1897, 116; Chester, Man. Determ. Bact., 1901, 177.) From air.

Bakterium flaveum Wilhelmy. (Arb. bakt. Inst. Karlsruhe, *3*, 1903, 15.) From meat extract.

Bacterium flavocoriaceum (Eisenberg) Chester. (Schwefelgelber Bacillus, Adametz and Wichmann, Die Bakterien der Trink- und Nutzwässer, Mitt. Oest. Versuchsstat. f. Brauerei u. Mälz., Wien, Heft 1, 1888, 49; *Bacillus flavocoriaceus* Eisenberg, Bakt. Diag., 3 Aufl., 1891, 144; Chester, Ann. Rept. Del. Col. Agr. Exp. Sta., *9*, 1897, 112.) From water.

Bacterium flavofuscum Migula. (No. 9, Lembke, Arch. f. Hyg., *26*, 1896, 304; Migula, Syst. d. Bakt., *2*, 1900, 479.) From meat.

Bacterium flavum Issatchenko. (Recherches sur les microbes de l'Océan Glacial Arctique (in Russian). Petrograd, 1914, 151.) From sea water.

Bacterium foliicola (Miehe) de Jongh. (*Bacillus foliicola* Miehe, see Jahrb. wiss. Bot., *53*, 1914, 1; *ibid.*, *58*, 1919, 29; de Jongh, On the Symbiosis of *Ardisia crispa*. Thesis, Univ. Leiden, 1938, 33.) A bacterial symbiont isolated from germinating seeds and embryos.

Bacterium freundii Migula. (Bacillus nova species I, Freund, Inaug. Diss., Erlangen, 1893, 31; Migula, Syst. d. Bakt., *2*, 1900, 472.) From the mouth cavity.

Bacterium fungoides (Tschistowitsch) Migula. (*Bacillus fungoides* Tschistowitsch, Berl. klin. Wochnschr., 1892, 513; Migula, Syst. d. Bakt., *2*, 1900, 391.) From pus.

Bacterium fuscum (Flügge) Migula. (*Bacillus fuscus* Flügge, Die Mikroorganismen, 2 Aufl., 1886, 290; Migula, Syst. d. Bakt., *2*, 1900, 463.) From water.

Bacterium gamma (Dyar) Chester. (*Bacillus gamma* Dyar, Ann. N. Y. Acad. Sci., *8*, 1895, 367; Chester, Ann. Rept. Del. Col. Agr. Exp. Sta., *9*, 1897, 106.) From air.

Bacterium gammari Vejdovsky. (Cent. f. Bakt., II Abt., *11*, 1904, 484.) From sections of a fresh water crustacean (*Gammarus zschokkei*). Cells exhibit nuclei, showing mitosis.

Bacterium gelechiae No. 1 and No. 2, Metalnikov and Metalnikov. (Compt. rend. Acad. Agr., France, *18*, 1932, 204.) From dead and dying larvae of a moth (*Gelechia gossypiella*).

Bacterium gelechiae No. 5, Metalnikov and Meng. (Compt. rend. Soc. Biol., Paris, *113*, 1933, 170.) From dead larvae of a moth (*Gelechia gossypiella*).

Bacterium gemmiforme Migula. (Lembke, Arch. f. Hyg., *29*, 1897, 313; Migula, Syst. d. Bakt., *2*, 1900, 391.) From intestinal contents.

Bacterium gibbosum Weiss. (Arb. bakt. Inst. Karlsruhe, *2*, Heft 3, 1902, 230.) From fermenting beets and malt.

Bacterium gingivae pyogenes Miller. (Miller, Die Mikroorganismen der Mundhöhle, Leipzig, 1888, 217; *Bacillus gingivae pyogenes* Sternberg, Manual of Bact., 1893, 471.) From an alveolar abscess.

Bacterium gingivitidis (Kruse) Migula. (Babes, Deutsch. med. Wochnschr., 1893, 1035; *Bacillus gingivitidis* Kruse, in Flügge, Die Mikroorganismen, 3 Aufl., *2*, 1896, 427; Migula, Syst. d. Bakt., *2*, 1900, 393.) Isolated in an epidemic of scurvy in Jassy.

Bacterium gliscrogenum Malerba and Sanna-Salaris. (Malerba and Sanna-Salaris, Lavori eseguiti nell'Istituto fisiol. di Napoli, *2*, 1888, 13 and 95; *Bacillus gliscrogenus* Trevisan, I generi e le specie delle Batteriacee, 1889, 14.) From urine.

Bacterium gonnermanni Migula. (*Bacillus tuberigenus 6* Gonnermann, Land-

wirtsch. Jahrb., *23*, 1894, 657; Migula, Syst. d. Bakt., *2*, 1900, 418.) From root nodules of lupine.

Bacterium gracilescens Weiss. (Arb. bakt. Inst. Karlsruhe, *2*, Heft 3, 1902, 259.) From fermenting asparagus and malt.

Bacterium gracillimum Weiss. (Arb. bakt. Inst. Karlsruhe, *2*, Heft 3, 1902, 235.) From bean and asparagus infusions.

Bacterium granulatum Henrici. (Henrici, Arb. bakt. Inst. Karlsruhe, *1*, Heft 1, 1894, 33; not *Bacterium granulatum* Chester, Man. Determ. Bact., 1901, 189.) From cheese.

Bacterium granulosum Weiss. (Weiss, Arb. bakt. Inst. Karlsruhe, *2*, Heft 3, 1902, 212; not *Bacterium granulosum* Lehmann and Neumann, Bakt. Diag., 5 Aufl., *2*, 1912, 306.) From vegetable infusions.

Bacterium gryllotalpae Metalnikov and Meng. (Compt. rend. Acad. Sci., Paris, *201*, 1935, 367.) From diseased larvae of the cricket (*Gryllotalpa gryllotalpa*).

Bacterium gummosum Ritsert. (Ritsert, Ber. d. pharmaz. Gesell., *1*, 1891, 389; abst. in Cent. f. Bakt., *11*, 1892, 730; *Bacillus gummosus* Migula, Syst. d. Bakt., *2*, 1900, 873.) A mixture of a spore-forming rod and a streptococcus. See *Bacillus gummosus* Happ and *Micrococcus gummosus* Happ.

Bacterium halans (Zimmermann) Migula. (*Bacillus halans* Zimmermann, Die Bakterien unserer Trink- u. Nutzwässer, Chemnitz, *2*, 1894, 54; Migula, Syst. d. Bakt., *2*, 1900, 429.) From water.

Bacterium hebetisiccus Steinhaus. (Jour. Bact., *42*, 1941, 762 and 773.) From the walking stick (*Diapheromera femorata*).

Bacterium herbicola α aureum Geilinger. (Mitteil. a. d. Gebiete d. Lebensmitteluntersuchungen u. Hyg., *12*, 1921, 262.) From corn meal. This is a variety of *Bacillus herbicola* Burri and Düggeli.

Bacterium herbicola rubrum Düggeli. (Düggeli, Cent. f. Bakt., II Abt., *12*, 1904, 605; *Bacterium herbicola β rubrum* Lehmann and Neumann, Bakt. Diag., 4 Aufl., *2*, 1907, 356.) From germinating plants, roots and barley seeds.

Bacterium hexacarbovorum Störmer. (Jahresber. d. Vereinigg. f. angew. Botanik, *5*, 1907, 116.) From soil. Utilizes benzene and certain benzene derivatives.

Bacterium hidium Goobin. (Russian Health Resort Service, *5*, 1923, 3.) Attacks ethane and other hydrocarbons.

Bacterium hirudinicolicum Lehmensick. (Cent. f. Bakt., I Abt., Orig., *147*, 1941, 317; see Biol. Abst., *18*, 1944, No. 6761.) Symbiotic in the intestines of *Hirudo officinalis* and *H. medicinalis*.

Bacterium hoshigaki var. *glucuronicum II* and *III* Takahashi and Asai. (Cent. f. Bakt., II Abt., *87*, 1933, 395 and 405.) From dried persimmons (hoshigaki).

Bacterium infecundum Chester. (*Bacillus filiformis havaniensis* Sternberg, Man. of Bact., 1893, 650; *Bacterium filiformis havaniensis* Chester, Ann. Rept. Del. Col. Agr. Exp. Sta., *9*, 1897, 126; Chester, Man. Determ. Bact., 1901, 184.) From the liver of a yellow fever cadaver. Anaerobic.

Bacterium inocuum Chester. (Wilde, Wien. klin. Wochnschr., 1892, No. 1–2; *Bacillus lactis inocuus* Kruse, in Flügge, Die Mikroorganismen, 3 Aufl., *2*, 1896, 352; *Bacterium lactis inocuus* Chester, Ann. Rept. Del. Col. Agr. Exp. Sta., *9*, 1897, 82; Chester, Man. Determ. Bact., 1901, 138.) From milk.

Bacterium intrinsectum Steinhaus. (Jour. Bact., *42*, 1941, 764 and 774.) From an unidentified leaf beetle.

Bacterium iogenum Baumgartner. (Deutsche Monatschr. f. Zahnheilk., *27*, 764; *Bacterium jogenum* Baumgartner, Ergeb. d. gesam. Zahnheilk., *1*, 1911, 752 and 779; *B. iogenum* Kligler, Jour. Allied Dent. Soc., *10*, 1915, 152.) From the mouth. Regarded as identical with *Jodococcus vaginatus* Miller by Kligler (*loc. cit.*).

Bacterium keratomalaciae Migula. (*Bacillus septicus keratomalaciae* Babes,

Bakteriol. Untersuch. d. sept. Prozesse d. Kindesalters, Leipzig, 1889; Migula, Syst. d. Bakt., *2*, 1900, 363.) From an infected cornea.

Bacterium knipowitchi Issatchenko. (Recherches sur les microbes de l'Océan Glacial Arctique (in Russian). Petrograd, 1914, 150.) From sea water. A phosphorescent bacterium found to be pathogenic for the mealworm (*Tenebrio molitor*) by Pfeiffer and Stammer (Ztschr. f. Morph. u. Ökol. d. Tiere, *20*, 1930, 157).

Bacterium kralii (Dyar) Chester. (*Bacillus kralii* Dyar, Ann. N. Y. Acad. Sci., *8*, 1895, 376; Chester, Ann. Rept. Del. Col. Agr. Exp. Sta., *9*, 1897, 93; not *Bacterium kralii* Chester, Man. Determ. Bact., 1901, 166.) Received as *Bacillus butyricus* from Kràl's laboratory by Dyar. The 1900 Kràl Catalogue lists cultures of *Bacillus butyricus* Botkin and *Bacillus butyricus* Hueppe. As Dyar found that the characters of his culture differed from those of *Bacillus butyricus* Hueppe, Dyar's culture was probably *Bacillus butyricus* Botkin.

Bacterium kralii Chester. (*Bacillus fuscus liquefaciens* Dyar, Ann. N. Y. Acad. Sci., *8*, 1895, 375; *Bacterium fuscus liquefaciens* Chester, Ann. Rept. Del. Col. Agr. Exp. Sta., *9*, 1897, 108; Chester, Man. Determ. Bact., 1901, 166.) Received as *Bacillus fuscus* from Kràl's laboratory by Dyar who also found it in air. The 1920 Kràl catalogue lists *Bacillus fuscus* Flügge syn. *Bacterium brunneum* Schrötter (sic); braunrother Bacillus Maschek.

Bacterium laerii Migula. (*Bacillus viscosus No. 1*, van Laer, Extrait des mémoires couronnés et autres mémoires, Acad. Royale de Belgique, 1889, 36; see Kramer, Bakteriol. in ihren Beziehungen zur Landwirtsch., *2*, 1892, 119; *Bacillus viscosus cerevisiae* Kruse, in Flügge, Die Mikroorganismen, 3 Aufl., *2*, 1896, 359; *Bacterium viscosus cerevisiae* Chester, Ann. Rept. Del. Col. Agr. Exp. Sta., *9*, 1897, 78; Migula, Syst. d. Bakt., *2*, 1900, 402; *Bacterium viscosum* Chester, Man. Determ. Bact., 1901, 128.) From beer, yeast, air, bread. Causes a slimy fermentation.

Bacterium laevolacticum Migula. (*Bacillus acidi laevolactici* Schardinger, Monatsh. f. Chemie, *11*, 1890, 544; Migula, Syst. d. Bakt., *2*, 1900, 406; *Bacterium acidi laevolactici* Lehmann and Neumann, Bakt. Diag., 4 Aufl., *2*, 1907, 178.) From milk.

Bacterium laminariae Billet. (Compt. rend. Acad. Sci., Paris, *106*, 1888, 293; *Billetia laminariae* Trevisan, I generi e le specie delle Batteriacee, 1889, 11; *Kurthia laminariae* De Toni and Trevisan, in Saccardo, Sylloge Fungorum, *8*, 1889, 931.) From rotting sea weed. The type species of the genus *Billetia* Trevisan.

Bacterium langkatense Honing. (Cent. f. Bakt., II Abt., *37*, 1913, 381.) From tobacco plants in Sumatra.

Bacterium largum (v. Klecki) Migula. (*Bacillus largus* v. Klecki, Ann. Inst. Past., *9*, 1898, 728; Migula, Syst. d. Bakt., *2*, 1900, 448.) From the intestines of dogs.

Bacterium lepierrei Chester. (Bacille fluorescent pathogène, Lepierre, Ann. Inst. Past., *9*, 1895, 643; Chester, Man. Determ. Bact., 1901, 182.) From cistern water.

Bacterium lethalis (Babes) Chester. (*Proteus lethalis* Babes, Progrès Médical Roumain, 1889; Chester, Ann. Rept. Del. Col. Agr. Exp. Sta., *9*, 1897, 104; *Bacillus lethalis* Chester, Man. Determ. Bact., 1901, 249.) From lung gangrene in man.

Bacterium leucaemiae Migula. (Lucet, Jahresber. ü. Fortschr. in d. Lehre v. d. path. Mikroorg., *7*, 1891, 319; *Bacillus leucaemiae canis* Kruse, in Flügge, Die Mikroorganismen, 3 Aufl., *2*, 1896, 285; *Bacterium leucaemiae canis* Chester, Ann. Rept. Del. Col. Agr. Exp. Sta., *9*, 1897, 119; Migula, Syst. d. Bakt., *2*, 1900, 442; *Bacillus leucaemiae* Chester, Man. Determ. Bact., 1901, 264.) From a dog with leukemia.

Bacterium limbatum Migula. (*Bacterium limbatum acidi lactici* Marpmann,

Ergänzungshefte d. Centralb. f. allg. Gesundheitspflege, *2*, 122; *Bacillus limbatus acidi lactici* Sternberg, Man. of Bact., 1893, 645; Migula, Syst. d. Bakt., *2*, 1900, 407.) From fresh milk.

Bacterium lineola (Müller) Cohn. (*Vibrio lineola* Müller, Vermium Historia, 1773, 39; Cohn, Beitr. z. Biol. d. Pflanz., *1*, Heft 2, 1872, 170; *Bacillus lineola* Trevisan, I generi e le specie delle Batteriacee, 1889, 18.) From stagnant water, infusions, etc.

Bacterium lini Migula. (Winogradsky, Compt. rend. Acad. Sci., Paris, *121*, 1893, 742; Migula, Syst. d. Bakt., *2*, 1900, 513.) From retting hemp.

Bacterium linkoi Issatchenko. (Recherches sur les microbes de l'Océan Glacial Arctique (in Russian). Petrograd, 1914, 154.) From sea water.

Bacterium liquefaciens communis (Sternberg) Chester. (*Bacillus liquefaciens communis* Sternberg, Man. of Bact., 1893, 686; Chester, Ann. Rept. Del. Col. Agr. Exp. Sta., *9*, 1897, 91; *Bacillus communis* Migula, Syst. d. Bakt., *2*, 1900, 725; not *Bacillus communis* Jackson, Jour. Inf. Dis., *8*, 1911, 241.) From the feces of yellow fever patients.

Bacterium litoreum Warming. (Warming, Danmarks Kyster levende Bakterier, 1875, 398; *Bacillus litoreus* Trevisan, I generi e le specie delle Batteriacee, 1889, 18.) From sea water.

Bacterium loculosum Migula. (Fächerbacillus, Clauss, Inaug. Diss., Würzburg, 1889, 27; Migula, Syst. d. Bakt., *2*, 1900, 408.) From milk.

Bacterium luceti Migula. (Lucet, Ann. Inst. Past., *3*, 1889, 401; *Bacillus cuniculicida thermophilus* Kruse, in Flügge, Die Mikroorganismen, 3 Aufl., *2*, 1896, 418; Migula, Syst. d. Bakt., *2*, 1900, 507; *Bacterium cuniculicida thermophilus* Chester, Ann. Rept. Del. Col. Agr. Exp. Sta., *9*, 1897, 83; *Bacterium cuniculicida* Chester, Man. Determ. Bact., 1901, 140.) Associated with an epizootic in rabbits and guinea pigs.

Bacterium ludwigi Karlinski. (Hyg. Rundschau, *5*, 1895, 685.) From the water of the hot springs at Ilidze in Bosnia.

Bacterium luteolum Henrici. (Henrici, Arb. bakt. Inst. Karlsruhe, *1*, Heft 1, 1894, 51; Migula, Syst. d. Bakt., *2*, 1900, 455.) From cheese.

Bacterium lutescens Migula. (Der gelbe Bacillus, Lustig, Diag. d. Bakt. d. Wassers, 1893, 78; Migula, Syst. d. Bakt., *2*, 1900, 476.) From water.

Bacterium luteum Adametz. (List, Inaug. Diss., Leipzig, 1885, 53; Adametz, Bakt. Nutz- u. Trinkwässer, Mitteil. d. österr. Versuchsstation für Brauerei und Mälzerei in Wien, 1888, 48.) From the stomach contents of sheep and from water.

Bacterium margarineum Migula. (Margarinbacillus α, Jolles and Winkler, Ztschr. f. Hyg., *20*, 1895, 102; Migula, Syst. d. Bakt., *2*, 1900, 410.) From margarine.

Bacterium marinum Issatchenko. (Recherches sur les microbes de l'Océan Glacial Arctique (in Russian). Petrograd, 1914, 238.) From sea water.

Bacterium maydis Maiocchi. (Maiocchi, Bollet. d. Accad. medic. d. Roma, October, 1881; *Bacillus maydis* Trevisan, I generi e le specie delle Batteriacee, 1889, 17.) From corn (maize) infusions.

Bacterium medanense Honing. (Cent. f. Bakt., II Abt., *37*, 1913, 382.) From the peanut plant (*Arachis hypogaea*).

Bacterium melolonthae liquefaciens Paillot. (Compt. rend. Soc. Biol., Paris, *68*, 1916, 1102.) From the cockchafer (*Melolontha melolontha*). According to the author's system of nomenclature, this is presumably a synonym of *Bacillus melolonthae liquefaciens α*.

Bacterium meningitidis (Neumann and Schaffer) Chester. (*Bacillus meningitidis purulentae* Neumann and Schaeffer, Arch. f. path. Anat., *109*, 1887, 477; Chester, Ann. Rept. Del. Col. Agr. Exp. Sta., *9*, 1897, 71; *Bacillus neumanni* Migula, Syst. d. Bakt., *2*, 1900, 751; not *Bacillus neumanni* Herter, in Just, Botan. Jahresber., 2 Abt., *39*, Heft 4, 1915, 748; *Bacillus meningitidis* Chester,

Man. Determ. Bact., 1901, 213.) From pus from an individual who died of purulent meningitis.

Bacterium merismopedioides Zopf. (Zopf, Die Spaltpilze, 1 Aufl., 1883, 56; *Bacillus synchyseus* Trevisan, I generi e le specie delle Batteriacee, 1889, 18; *Bacterium synchyseus* DeToni and Trevisan, in Saccardo, Sylloge Fungorum, *8*, 1889, 1022.) From canal water.

Bacterium microsporum Trevisan. (Trevisan, Rendic. d. Instit. Lombardo, Ser. 2, *13*, 1879; *Bacillus microtis* Trevisan, I generi e le specie delle Batteriacee, 1889, 18; *Bacterium microtis* DeToni and Trevisan, in Saccardo, Sylloge Fungorum, *8*, 1889, 1025.) From water and putrefying infusions.

Bacterium minutum (Zimmermann) Migula. (*Bacillus minutus* Zimmermann, Die Bakterien unserer Trink- und Nutzwässer, Chemnitz, *2*, 1894, 56; Migula, Syst. d. Bakt., *2*, 1900, 423.) From water.

Bacterium monachae von Tubeuf. (v. Tubeuf, Forstlich - naturwissensch. Ztschr., *1*, 1892, 34; *Bacillus monachae* Migula, Syst. d. Bakt., *2*, 1900, 742.) From the larvae of a moth (*Lymantria monacha*).

Bacterium multipediculum (Flügge) Chester. (*Bacillus multipediculus* Flügge, Die Mikroorganismen, 2 Aufl., 1886, 323; Chester, Ann. Rept. Del. Col. Agr. Exp. Sta., *9*, 1897, 104.) Isolated frequently as a contamination on potato media.

Bacterium muripestifer (Kruse) Chester. (Bacillus der Mäuseseuche, Laser, Cent. f. Bakt., *11*, 1892, 184; *Bacillus muripestifer* Kruse, in Flügge, Die Mikroorganismen, 3 Aufl., *2*, 1896, 432; Chester, Ann. Rept. Del. Col. Agr. Exp. Sta., *9*, 1897, 87.) From the spleen of a field mouse. Associated with a plague of field mice.

Bacterium nacreaceum (Zimmermann) Migula. (Perlmutterglänzender Bacillus, Keck, Inaug. Diss., Dorpat, 1890, 40; Eberbach, Inaug. Diss., Dorpat, 1890; *Bacillus nacreaceus* Zimmermann, Die Bakterien unserer Trink- und Nutzwässer, Chemnitz, *2*, 1894, 34; Migula, Syst. d. Bakt., *2*, 1900, 426.) From water.

Bacterium naphthalinicus Tausson. (Planta, *4*, 1927, 214.) From oil-soaked soils at Baku, Russia. Oxidizes naphthalene.

Bacterium nicolaieri Migula. (Kapselbacillus, Nicolaier, Cent. f. Bakt., *16*, 1894, 601; Migula, Syst. d. Bakt., *2*, 1900, 354.) Associated with purulent nephritis.

Bacterium nicotianum Bucherer. (Cent. f. Bakt., II Abt., *105*, 1942–43, 446.) From fermenting tobacco leaves.

Bacterium nicotinobacter Bucherer. (Cent. f. Bakt., II Abt., *105*, 1942, 170.) From a mixture of soil, manure and rotting materials. Gram-variable.

Bacterium nicotinophagum Bucherer. (Cent. f. Bakt., II Abt., *105*, 1942, 167.) From a mixture of soil, manure, and rotting materials. Also from fermenting tobacco leaves (*ibid.*, 446).

Bacterium nitens Kern. (Arb. bakt. Inst. Karlsruhe, *1*, Heft 4, 1896, 459.) From the intestines of birds.

Bacterium nomae (Schimmelbusch) Migula. (*Bacillus nomae* Schimmelbusch, Deutsch. med. Wochnschr., 1889, No. 26; Migula, Syst. d. Bakt., *2*, 1900, 384.) Found in necrotic tissues.

Bacterium oblongum (Boutroux) DeToni and Trevisan. (*Micrococcus oblongus* Boutroux, Annales de l'École normale supérieure, Sér. 2, *5*, 1881, 67; *Bacillus oblongus* Trevisan, I generi e le specie delle Batteriacee, 1889, 16; DeToni and Trevisan, in Saccardo, Sylloge Fungorum, *8*, 1889, 1021; *Bacterium gluconicum* Miquel and Cambier, Traité de Bact., 1902, 605; not *Bacterium gluconicum* Hermann, Biochem. Zeit., *192*, 1928, 198.) From vinegar. May be an acetobacter.

Bacterium ogatae Migula. (Ogata, Cent. f. Bakt., *9*, 1891, 442; Migula, Syst. d. Bakt., *2*, 1900, 389.) From dust.

Bacterium orchiticum (Kruse) Chester. (Bacillus zur Rotzdiagnose, Kutscher,

Ztschr. f. Hyg., *21*, 1895, 156; *Bacillus orchiticus* Kruse, in Flügge, Die Mikroorganismen, 3 Aufl., *2*, 1896, 455; Chester, Ann. Rept. Del. Col. Agr. Exp. Sta., *9*, 1897, 99.) From nasal secretions of a glandered horse.

Bacterium osteophilum Billet. (Contribution à l'étude de la morphologie et du développement des Bactériacées, Bull. Sci. de la France et de la Belgique, Paris, *21*, 1890, 149.) From macerated human bones.

Bacterium ovale Migula. (Bacillus No. 17, Pansini, Arch. f. pathol. Anat. u. Physiol., *122*, 1890, 451; Migula, Syst. d. Bakt., *2*, 1900, 458; not *Bacterium ovale* Chester, Man. Determ. Bact., 1901, 171 (*Bacillus ovalis* Wright, Mem. Nat. Acad. Sci., *7*, 1895, 435).) From feces.

Bacterium ovatum Migula. (*Bacillus ovatus minutissimus* Unna-Tommasoli, Monatsh. f. prakt. Dermatol., *9*, 1889, 59; Migula, Syst. d. Bakt., *2*, 1900, 417; *Bacterium ovatus minutissimus* Chester, Ann. Rept. Del. Col. Agr. Exp. Sta., *9*, 1897, 139; not *Bacterium ovatum* Chester, Man. Determ. Bact., 1901, 177 (*Bacillus ruber ovatus* Bruyning, Arch. néerl. Sci. exact. et nat., Sér. II, 1898, 297).) From human skin with seborrheic eczema.

Bacterium pallens Henrici. (Arb. bakt. Inst. Karlsruhe, *1*, Heft 1, 1894, 36.) From cheese.

Bacterium pallescens Henrici. (Arb. bakt. Inst. Karlsruhe, *1*, Heft 1, 1894, 35.) From cheese.

Bacterium pallidum Henrici. (Arb. bakt. Inst. Karlsruhe, *1*, Heft 1, 1894, 34; *Ulvina pallida* Pribram, Klassifikation der Schizomyceten, Leipzig und Wien, 1933, 76.) From cheese.

Bacterium pallidior Chester. (*Bacillus fuscus pallidior* Dyar, Ann. N. Y. Acad. Sci., *8*, 1895, 361; *Bacterium fuscus pallidior* Chester, Ann. Rept. Del. Col. Agr. Exp. Sta., *9*, 1897, 111; Chester, Man. Determ. Bact., 1901, 171.) Culture received by Dyar from Kràl's laboratory labeled *Bacillus latericeus*. Dyar renames this because the culture does not agree with *Bacillus latericeus* Eisenberg. However, the 1900 Kràl catalogue indicates that this was *Bacillus latericeus* Adametz and Wichmann syn. ziegelrother Bacillus, Adametz; *Bacterium lactericeum* Lehmann and Neumann.

Bacterium papillare Issatchenko. (Recherches sur les microbes de l'Océan Glacial Arctique (in Russian). Petrograd, 1914, 149.) From sea water.

Bacterium paradoxus (Kruse) Chester. (Typhus ahnlicher Bacillus, Kruse and Pasquale, Ztschr. f. Hyg., *16*, 1894, 19; *Bacillus paradoxus* Kruse, in Flügge, Die Mikroorganismen, 3 Aufl., *2*, 1896, 373; Chester, Ann. Rept. Del. Col. Agr. Exp. Sta., *9*, 1897, 71.) From the liver in a case of dysentery.

Bacterium paraviscosum Buchanan and Hammer. (Iowa Sta. Coll. Agr. Exp. Sta., Res. Bull. 22, 1915, 266.) Stated to be similar to *Bacterium viscosum* of various authors.

Bacterium patelliforme Honing. (Cent. f. Bakt., II Abt., *37*, 1913, 378.) From tobacco plants in Sumatra.

Bacterium pateriforme Migula. (*Bacillus albicans pateriformis* Unna-Tommasoli, Monatsh. prakt. Dermatol., *9*, 1889, 58; Migula, Syst. d. Bakt., *2*, 1900, 415.) Found on human skin with seborrheic eczema.

Bacterium petersii Migula. (Bacterium C, Peters, Botan. Zeitung, *47*, 1889; *Bacillus aceticus petersii* Kruse, in Flügge, Die Mikroorganismen, 3 Aufl., *2*, 1896, 355; *Bacterium aceticus petersii* Chester, Ann. Rept. Del. Col. Agr. Exp. Sta., *9*, 1897, 77; Migula, Syst. d. Bakt., *2*, 1900, 397; *Bacterium aceticum* Chester, Man. Determ. Bact., 1901, 127; not *Bacterium aceticum* Baginsky, Ztschr. f. phys. Chem., *12*, 1888, 437.) From fermenting dough.

Bacterium photometricum Engelmann. (Engelmann, Jour. Roy. Microscop. Soc., 1882, 656 and 1883, 256; *Bacillus photometricus* Trevisan, I generi e le specie delle Batteriacee, 1889, 18.) Saprophytic.

Bacterium piluliformans (Müller-Thur-

gau) Migula. (*Bacillus piluliformans* Müller-Thurgau, Jahresber. d. Versuchsstation zu Wädenswil 1892/3, *3*, 1894, 92; Migula, Syst. d. Bakt., *2*, 1900, 513.) From a disease of red wine.

Bacterium pituitosum Migula. (*Bacillus lactis pituitosi* Löeffler, Berliner klin. Wochnschr., 1887, 631; *Bacterium lactis pituitosi* Chester, Ann. Rept. Del. Col. Agr. Exp. Sta., *9*, 1897, 86; Migula, Syst. d. Bakt., *2*, 1900, 403; *Bacterium lactis* Chester, Man. Determ. Bact., 1901, 148; not *Bacterium lactis* Baginsky, Ztschr. f. phys. Chem., *12*, 1888, 437.) From milk.

Bacterium pityocampae Dufrenoy. (Compt. rend. Soc. Biol., Paris, *71*, 1919, 288.) From diseased caterpillars of the processionary moth (*Cnethocampa pityocampa*).

Bacterium pleuropneumoniae Migula. (Diplococcus der Brustseuche der Pferde, Schütz, Arch. f. pathol. Anat. u. Physiol., *107*, 374; Migula, Syst. d. Bakt., *2*, 1900, 348.) Frequently isolated from horses with pneumonia.

Bacterium plicatum (Zimmermann) Chester. (*Bacillus plicatus* Zimmermann, Die Bakterien unserer Trink- und Nutzwässer, Chemnitz, *1*, 1890, 54; Chester, Ann. Rept. Del. Col. Agr. Exp. Sta., *9*, 1897, 108; *Bacterium plicativum* Migula, Syst. d. Bakt., *2*, 1900, v and 453). From water.

Bacterium pneumopecurium Chester. (Bacillus of sporadic pneumonia of cattle, Smith, U. S. Dept. Agr. Bur. Animal Husbandry, 1895, 136; Chester, Man. Determ. Bact., 1901, 137.) Similar to *Pasteurella suilla*.

Bacterium pneumosepticum (Babes) Migula. (*Bacillus pneumosepticus* Babes, Progrès méd. roumain, *6*, 1889; not *Bacillus pneumosepticus* Kruse, in Flügge, Die Mikroorganismen, 3 Aufl., *2*, 1896, 408; Migula, Syst. d. Bakt., *2*, 1900, 377.) From a case of septic pneumonia.

Bacterium polymorphum (Frankland and Frankland) Migula. (*Bacillus polymorphus* Frankland and Frankland, Philos. Trans. Royal Soc. London, *178*, 1887, B, 275; Migula, Syst. d. Bakt., *2*, 1900, 420.) From air.

Bacterium porri Majocchi. (Majocchi, in Tommasi-Crudeli, Anatomia patologica, *1*, 1882; *Bacillus verrucae vulgaris* Kuhnemann, Monatsh. f. prakt. Dermatol., *9*, 1889; *Bacillus porri* Trevisan, I generi e le specie delle Batteriacee, 1889, 13.) From warts.

Bacterium prodeniae Metalnikov and Metalnikov. (Compt. rend. Acad. Agric., France, *18*, 1932, 206.) From a blackened dead larva of a moth (*Prodenia litura*).

Bacterium profusum (Frankland and Frankland) Migula. (*Bacillus profusus* Frankland and Frankland, Philos. Trans. Royal Soc. London, *178*, 1887, B, 276; Migula, Syst. d. Bakt., *2*, 1900, 421.) From air.

Bacterium pseudoaquatile Migula. (*Bacillus aquatilis* α, Tataroff, Inaug. Diss., Dorpat, 1891, 44; Migula, Syst. d. Bakt., *2*, 1900, 470.) From water.

Bacterium pseudoconjunctivilidis (Kruse) Chester. (Kartulis, Cent. f. Bakt., *1*, 1887, 289; *Bacillus pseudoconjunctivitidis* Kruse, in Flügge, Die Mikroorganismen, 3 Aufl., *2*, 1896, 441; Chester, Ann. Rept. Del. Col. Agr. Exp. Sta., *9*, 1897, 108.) From conjunctival secretions.

Bacterium pseudofilicinum Migula. (Fadenbacillus, Maschek, Bakteriologische Untersuchungen der Leitmeritzer Trinkwässer, Leitmeritz, 1887; Migula, Syst. d. Bakt., *2*, 1900, 454.) From water.

Bacterium pseudoinfluenzae (Kruse) Chester. (Pseudoinfluenzabacillus, Pfeiffer, Ztschr. f. Hyg., *13*, 1893, 357; *Bacillus pseudoinfluenzae* Kruse, in Flügge, Die Mikroorganismen, 3 Aufl., *2*, 1896, 439; Chester, Ann. Rept. Del. Col. Agr. Exp. Sta., *9*, 1897, 66.) From water.

Bacterium pseudokeratomalaciae Migula. (Loeb, Cent. f. Bakt., *10*, 1891, 369; Migula, Syst. d. Bakt., *2*, 1900, 359.)

A capsulated bacterium from infected cornea of a child.

Bacterium pseudomultipediculum Migula. (*Bacillus multipediculus flavus* Zimmermann, Bakt. unser. Trink- u. Nutzwässer, Chemnitz, *2*, 1894, 42; Migula, Syst. d. Bakt., *2*, 1900, 332.) From sewage.

Bacterium pseudopneumonicum (Passet) Chester. (*Bacillus pseudopneumonicus* Passet, Untersuchungen über die Aetiologie der eiterigen Phlegmone des Menschen, 1885, 40; Chester, Ann. Rept. Del. Col. Agr. Exp. Sta., *9*, 1897, 140; *Brucella pseudopneumonicum* Pribram, Klassifikation der Schizomyceten, Leipzig und Wien, 1933, 68.) From pus.

Bacterium punctum (Mueller) Ehrenberg. (*Monas punctum* Mueller, Infusoria, 1786, 3; *Bacillus punctum* Trevisan, I generi e le specie delle Batteriacee, 1889, 18.) From swamps and stagnant water.

Bacterium putidum Chester. (*Bacillus gracilis cadaveris* Sternberg, Man. of Bact., 1893, 733; Chester, Man. Determ. Bact., 1901, 140.) From a liver.

Bacterium pyaemicum Migula. (Levy, Cent. f. klin. Med., 1890, No. 4; abst. in Cent. f. Bakt., *8*, 1890, 86; Migula, Syst. d. Bakt., *2*, 1900, 443.) From a case of pyemia.

Bacterium pyocinnabareum (Kruse) Chester. (Ferchmin, Ueber rote Eiterung, Wratsch, 1892, No. 24 and 25; abst. in Cent. f. Bakt., *13*, 1893, 103; *Bacillus pyocinnabareus* Kruse, in Flügge, Die Mikroorganismen, 3 Aufl., *2*, 1896, 304; Chester, Ann. Rept. Del. Col. Agr. Exp. Sta., *9*, 1897, 113.) From a case of red pus.

Bacterium pyogenes Chester. (Fuchs, Inaug. Diss., Greifswald, 1890; *Bacillus pyogenes anaerobius* Kruse, in Flügge, Die Mikroorganismen, 3 Aufl., *2*, 1896, 244; not *Bacillus pyogenes anaerobius* Béla-Johan, Cent. f. Bakt., I Abt., Orig., *87*, 1922, 290; *Bacterium pyogenes anaerobius* Chester, Ann. Rept. Del. Col. Agr. Exp. Sta., *9*, 1897, 127; Chester, Man. Determ. Bact., 1901, 184; not *Bacterium pyogenes* Migula, Syst. d. Bakt., *2*, 1900, 381; not *Bacterium pyogenes* Ward, Jour. Bact., *2*, 1917, 619.) From stinking pus from a rabbit.

Bacterium pyraustae Nos. 1–7 Metalnikov and Chorine. (Internat. Corn Borer Invest., Sci. Repts., *1*, 1928, 52.) From diseased corn borer larvae (*Pyrausta nubilalis* Hb.).

Bacterium radiatum Chester. (Del. College Agr. Expt. Sta. Ann. Rept., *11*, 1900, 56.) From soil.

Bacterium ramificans Weiss. (Arb. bakt. Inst. Karlsruhe, *2*, Heft 3, 1902, 229.) From bean infusions.

Bacterium rangiferinum Honing. (Honing, Cent. f. Bakt., II Abt., *37*, 1913, 379; *Plocamobacterium rangiferinum* Pribram, Klassifikation der Schizomyceten, Leipzig und Wien, 1933, 78.) From fermenting tobacco.

Bacterium repens Miehe. An organism associated with *Bacterium foliicola* de Jongh.

Bacterium retiformans Gicklhorn. (Cent. f. Bakt., II Abt., *50*, 1920, 421.) A sulfur bacterium from garden soil. See Manual, 5th ed., 1939, 86 for a description of this organism.

Bacterium rhizopodicum Migula. (*Bacillus rhizopodicus margarineus* Jolles and Winkler, Ztschr. f. Hyg., *20*, 1895, 105; Migula, Syst. d. Bakt., *2*, 1900, 452.) From margarine.

Bacterium roseum Losski. (Losski, Inaug. Diss., Dorpat, 1893; quoted from Migula, Syst. d. Bakt., *2*, 1900, 484; *Bacillus roseus* Nepveux, Thèse, Fac. Pharm., Paris, 1920, 115.) From sand.

Bacterium rubigenosum Kern. (Kern, Arb. bakt. Inst. Karlsruhe, *1*, Heft, 4, 1896, 456; *Bacillus rubigenosus* Nepveux, Thèse, Fac. Pharm., Paris, 1920, 113; not *Bacillus rubiginosus* Catiano, in Cohn, Beitr. z. Biol. d. Pflanzen, *7*, 1896, 538.) From the intestines of birds.

Bacterium rubrum Schneider. (*Bakterium rubrum* Schneider, Arb. bakt. Inst. Karlsruhe, *1*, Heft 2, 1894, 213; also see Migula, Syst. d. Bakt., *2*, 1900, 488; *Bacillus rubrum* Nepveux, Thèse,

Fac. Pharm., Paris, 1920, 115.) From swamp water. Difficult to distinguish from *Bacterium erythromyxa*.

Bacterium rubrum Metalnikov and Metalnikov. (Compt. rend. Acad. Agric., France, *18*, 1932, 204; not *Bacterium rubrum* Schneider, Arb. bact. Inst. Karlsruhe, *1*, Heft 2, 1894, 213.) From the cotton worm (*Gelechia gossypiella*).

Bacterium salivae Migula. (*Bacillus salivae minutissimus* Kruse, in Flügge, Die Mikroorganismen, 3 Aufl., *2*, 1896, 440; *Bacterium salivae minutissimus* Chester, Ann. Rept. Del. Col. Agr. Exp. Sta., *9*, 1897, 86; Migula, Syst. d. Bakt., *2*, 1900, 418.) From secretions of the mouth.

Bacterium salmonicida Lehmann and Neumann. (Bacillus der Forellenseuche, Emmerich and Weibel, Arch. f. Hyg., *21*, 1894, 1; Lehmann and Neumann, Bakt. Diag., 1 Aufl., *2*, 1896, 240; *Bacillus salmonicida* Kruse, in Flügge, Die Mikroorganismen, 3 Aufl., *2*, 1896, 322; *Bacterium salmonica* Chester, Ann. Rept. Del. Col. Agr. Exp. Sta., *9*, 1897, 99; see Mackie et al., Final Rept. of the Furunculosis Committee, H. M. Stationery Office, Edinburgh, 1935; and Duff, Jour. Bact., *34*, 1937, 49.) Pathogenic for trout.

Bacterium sanguinis Migula. (*Bacillus sanguinis typhi* Sternberg, Man. of Bact., 1893, 732; *Bacterium sanguinis typhi* Chester, Ann. Rept. Del. Col. Agr. Exp. Sta., *9*, 1897, 89; Migula, Syst. d. Bakt., *2*, 1900, 506.) From the blood of typhus fever patients.

Bacterium schüffneri Honing. (Cent. f. Bakt., II Abt., *37*, 1913, 370.) From tobacco plants in Sumatra.

Bacterium septentrionale Issatchenko. (Recherches sur les microbes de l Océan Glacial Arctique (in Russian). Petrograd, 1914, 239.) From sea water.

Bacterium (*Proteus*) *septicus* (Babes) Chester. (*Proteus septicus* Babes, Septische Processe des Kindesalters, 1889; *Bacillus proteus septicus* Kruse, in Flügge, Die Mikroorganismen, 3 Aufl., *2*, 1896, 279; Chester, Ann. Rept. Del. Col. Agr. Exp. Sta., *9*, 1897, 102; *Bacillus septicus* Chester, Man. Determ. Bact., 1901, 245; not *Bacillus septicus* Macé, Traité pratique de Bact., 1st ed., 1889, 455; not *Bacillus septicus* Migula, Syst. d. Bakt., *2*, 1900, 646; not *Bacillus septicus* Crookshank, Textb. of Bact., 4th ed., 1900, 632.) From the intestine of a child having septicemia.

Bacterium setosum Henrici. (Arb. bakt. Inst. Karlsruhe, *1*, Heft 1, 1894, 46.) From cheese.

Bacterium siccum Issatchenko. (Recherches sur les microbes de l'Océan Glacial Arctique (in Russian). Petrograd, 1914, 235.) From sea water.

Bacterium sieberti Migula. (Siebert, Inaug. Diss., Würzburg, 1894, 13; Migula, Syst. d. Bakt., *2*, 1900, 456.) From hair follicles.

Bacterium soriferum Migula. (Severin, Cent. f. Bakt., II Abt., *1*, 1895, 799; Migula, Syst. d. Bakt., *2*, 1900, 438.) From manure.

Bacterium spiniferum (Unna-Tommasoli) Chester. (*Bacillus spiniferus* Unna-Tommasoli, Monatsh. f. prakt. Dermatol., *9*, 1889, 58; Chester, Ann. Rept. Del. Col. Agr. Exp. Sta., *9*, 1897, 110 and 143.) From human skin with seborrheic eczema.

Bacterium spinosum Weiss. (Arb. bakt. Inst. Karlsruhe, *2*, Heft 3, 1902, 219.) From fermenting beets.

Bacterium spirale Issatchenko. (Recherches sur les microbes de l'Océan Glacial Arctique (in Russian). Petrograd, 1914, 238.) From sea water.

Bacterium sputigenum Chester. (*Bacillus aerogenes sputigenus capsulatus* Herla, Archiv de Biol., *14*, 1895, 403; Chester, Man. Determ. Bact., 1901, 133; not *Bacterium sputigenum* Migula, Syst. d. Bakt., *2*, 1900, 378.) From the blood of a mouse which had been inoculated with the sputum of a pneumonia patient.

Bacterium sputigenum Migula. (Kreibohm, Inaug. Diss., Helmstedt, 1898, 29; Migula, Syst. d. Bakt., *2*, 1900, 378.) From the mouth.

Bacterium squamatum Weiss. (Arb. bakt. Inst. Karlsruhe, *2*, Heft 3, 1902, 242.) From vegetable infusions.

Bacterium squamosum Kern. (Arb. bakt. Inst. Karlsruhe, *1*, Heft 4, 1897, 436.) From the stomachs and intestines of birds.

Bacterium stalactitigenes Honing. (Cent. f. Bakt., II Abt., *37*, 1913, 375.) From tobacco plants in Sumatra.

Bacterium sternbergii Migula. (*Bacillus anaerobius liquefaciens* Sternberg, Man. of Bact., 1893, 693; Migula, Syst. d. Bakt., *2*, 1900, 444; *Bacterium anaerobicum* Chester, Man. Determ. Bact., 1901, 198; *Bacillus sternbergii* Winslow, Kligler and Rothberg, Jour. Bact., *4*, 1919, 487.) From intestines of yellow fever cadavers.

Bacterium steroidiclasium Arnaudi and Ercoli. (Boll. Sez. ital. Soc. intern. Microbiol., *20* (3), 1941, 000; also see Arnaudi, Cent. f. Bakt., II Abt., *105*, 1942–43, 352.) Source not given in second paper. From bakers' yeast.

Bacterium streckeri (Trevisan) Migula. (*Bacillus citreus cadaveris* Strassmann and Strecker, Ztschr. f. Medizinalbeamte, 1888, No. 3; *Bacillus streckeri* Trevisan, I generi e le specie delle Batteriacee, 1889, 17; *Bacterium citreus cadaveris* Chester, Ann. Rept. Del. Col. Agr. Exp. Sta., *9*, 1897, 108; Migula, Syst. d. Bakt., *2*, 1900, 460; *Bacterium citreum* Chester, Man. Determ. Bact., 1901, 167.) From a cadaver.

Bacterium subcitricum Weiss. (Arb. bakt. Inst. Karlsruhe, *2*, Heft 3, 1902, 257.) From vegetable infusions.

Bacterium subfuscum Kern. (Arb. bakt. Inst. Karlsruhe, *1*, Heft 4, 1896, 461.) From the intestines of birds.

Bacterium subluteum Migula. (*Bacillus luteus* von Dobrzyniecki, Cent. f. Bakt., I Abt., *21*, 1897, 835; Migula, Syst. d. Bakt., *2*, 1900, 456.) From the mouth.

Bacterium sulfureum Holschewnikoff. (Holschewnikoff, Fortschr. d. Med., *7*, 1889, 204 and Ann. de Microgr., *1*, 1888–1889, 261; *Bacillus sulfureus* Trevisan, I generi e le specie delle Batteriacee, 1889, 17.) From sewage.

Bacterium sumatranum Honing. (Cent. f. Bakt., II Abt., *37*, 1913, 374.) From tobacco plants in Sumatra.

Bacterium surgeri (Dornic and Daire) Buchanan and Hammer. (*Bacillus surgeri* Dornic and Daire, Bull. mens. de l'Office de renseignements agricoles, *6*, 1907, 146; Buchanan and Hammer, Iowa Sta. Coll. Agr. Exp. Sta., Res. Bull. 22, 1915, 254.) From serum produced in the manufacture of casein. Causes slimy milk. Closely related to the *Bacterium bulgaricum* group, according to Buchanan and Hammer.

Bacterium sycosiferum Migula. (*Bacillus sycosiferus foetides* Unna-Tommasoli, Monatsh. f. prakt. Dermatol., *8*, 1889, 183; Migula, Syst. d. Bakt., *2*, 1900, 385.) From the beard of a patient with bacillogenic sycosis.

Bacterium syphilidis (Kruse) Migula. (Syphilisbacillus, Lustgarten, Wiener med. Wochnschr., 1884 and Wiener med. Jahrbücher, 1885; *Pacinia syphilitica* Trevisan, I generi e le specie delle Batteriacee, 1889, 23; *Bacillus syphilidis* Kruse, in Flügge, Die Mikroorganismen, 3 Aufl., *2*, 1896, 514; Migula, Syst. d. Bakt., *2*, 1900, 496.) From syphilis.

Bacterium tachytonum Fischer. (Fischer, Deutsche med. Wochnschr., 1894, No. 25–28; *Bacillus tachytonus* Migula, Syst. d. Bakt., *2*, 1900, 655.) From feces in a case of cholera.

Bacterium tenue Migula. (*Bacillus tenuis sputigenes* Pansini, Arch. f. path. Anat., *122*, 1890, 453; *Bacillus sputigenus tenuis* (sic) Kruse, in Flügge, Die Mikroorganismen, 3 Aufl., *2*, 1896, 431; *Bacterium sputigenes tenuis* Chester, Ann. Rept. Del. Col. Agr. Exp. Sta., *9*, 1897, 89; Migula, Syst. d. Bakt., *2*, 1900, 457.) Associated with advanced phthisis and catarrhal pneumonia.

Bacterium termo (Mueller) Ehrenberg. (*Monas termo* Mueller, Infusoria, 1786; Ehrenberg, Abhandl. Akad. Berl., 1830; *Palmella infusionum* Ehrenberg, Infusionsthierchen, 1838, 526; *Zoogloea*

termo Cohn, Nova Acta Leop. Carol., *24*, 1853, 123; *Bacillus termo* Trevisan, I generi e le specie delle Batteriacee, 1889, 18.) From infusions.

Bacterium termo var. *subterraneum* Hansgirg. (Hansgirg, Oest. Bot. Ztschr., 1888, 6; quoted from DeToni and Trevisan, in Saccardo, Sylloge Fungorum, *8*, 1889, 1025.) From damp walls in a cellar.

Bacterium thiogenes Lehmann. (Thionsäurebakterien, Trautwein, Cent. f. Bakt., II Abt., *53*, 1921, 513; *ibid.*, *61*, 1924, 1; Lehmann, in Lehmann and Neumann, Bakt. Diag., 7th Aufl., *2*, 1927, 516; *Thiobacillus trautweinii* Bergey et al., Manual, 2nd ed., 1925, 39.) From canal water, sewage and soil. Regarded by Trautwein (*loc. cit.*, 1924, 5) as closely related to *Bacterium denitrificans* Lehmann and Neumann. See *Flavobacterium denitrificans* Bergey et al. Heterotrophic and therefore wrongly placed in *Thiobacillus* (Starkey, Jour. Bact., *28*, 1934, 387; Jour. Gen. Physiol., *18*, 1935, 325).

Bacterium tholoeideum Gessner. (Gessner, Arch. f. Hyg., *9*, 1889, 129; *Bacillus tholoeideus* DeToni and Trevisan, in Saccardo, Sylloge Fungorum, *8*, 1889, 952.) From the human duodenum.

Bacterium tortuosum Zukal. (Zukal, Verh. d. zoolog. botan. Gesellsch., Wien, *35*, 1885; *Bacillus tortuosus* Trevisan, I generi e le specie delle Batteriacee, 1889, 18; not *Bacillus tortuosus* Debono, Cent. f. Bakt., I Abt., Orig., *62*, 1912, 233.) From muddy water.

Bacterium tremulans Ehrenberg. (Ehrenberg, Abhandlungen d. Berliner Akad., 1830, 38; *Vibrio tremulans* Ehrenberg, Die Infusionsthierchen, 1838, 79; Trevisan, Rend. Ist. Lomb., 1879, 145; *Bacillus tremulans* Trevisan, I generi e le specie delle Batteriacee, 1889, 18.) From stagnant water, infusions, etc.

Bacterium trichorrhexidis Migula. (*Bacillus multiformis trichorrhexidis* Hodara, Monatsh. f. prakt. Dermatol., *19*, 1894, 173; Migula, Syst. d. Bakt., *2*, 1900, 437.) From healthy hair showing trichorrhexis.

Bacterium truncatum Chester. (Bacillus No. XII, Adametz, Landwirtsch. Jahrb., *18*, 1889; Chester, Man. Determ. Bact., 1901, 157; not *Bacterium truncatum* Migula, Syst. d. Bakt., *2*, 1900, 407; not *Bacterium truncatum* Chester, *loc. cit.*, 195.) From Emmenthal cheese.

Bacterium tuberosum Kern. (Arb. bakt. Inst. Karlsruhe, *1*, Heft 4, 1896, 455; *Bacillus tuberosus* Nepveux, Thèse, Fac. Pharm., Paris, 1920, 113.) From the intestines of birds.

Bacterium turcosum. (Quoted from Franke and Rudloff, Biochem. Ztschr., *310*, 1942, 207.) Source not given.

Bacterium uniforme Weiss. (Arb. bakt. Inst. Karlsruhe, *2*, Heft 3, 1902, 250.) From fermenting malt.

Bacterium ureae Leube and Graser. (Leube and Graser, Arch. f. pathol. Anat. u. Physiol., *100*, 1885, 558; *Bacillus ureae* Dyar, Ann. N. Y. Acad. Sci., *8*, 1895, 357; not *Bacillus ureae* Miquel, Bull. Soc. Chim. d. Paris, *31*, 1879, 391; *Urobacillus leubei* Miquel and Cambier, Traité de Bactériologie, Paris, 1902, 635; not *Urobacillus leubei* Beijerinck, Cent. f. Bakt., II Abt., 7, 1901, 51; *Plocamobacterium ureae* Pribram, Klassifikation der Schizomyceten, Leipzig und Wien, 1933, 78.) From urine. Leube makes no statement regarding spore formation. While Miquel's and Leube's organisms are sometimes regarded as having been identical, Miquel did not regard his *Bacillus ureae* as being identical with Leube's *Bacterium ureae* and gave them separate names *Urobacillus duclauxii* and *Urobacillus leubei* (Miquel and Cambier, *loc. cit.*, 631 and 635). The latter name had however been previously used by Beijerinck (*loc. cit.*) for a different organism. Dyar credits the name *Bacillus ureae* to Jaksch (Ztschr. f. physiol. Chem., *5*, 1881, 395) who, however, spoke only of a Harnstoffpilz and evidently had no pure cultures. Dyar's culture which came from Král is listed in the 1900 Král catalogue as

Bacillus ureae Leube. Also see Gibson (Jour. Bact., *24*, 1935, 493). Löhnis (Handb. f. landwirtsch. Bakt., 1910, 459) thinks that this species belongs in the *Proteus* group.

Bacterium vaillardi Migula. (Kelsch and Vaillard, Ann. Inst. Past., *4*, 1890, 276; Migula, Syst. d. Bakt., *2*, 1900, 437.) Found in swellings of the lymph system in leukemia.

Bacterium varicosum Migula. (Gombert, Recherches expér. microbes conjonctives, Paris, 1889; *Bacillus varicosus conjunctivae* Sternberg, Man. of Bact., 1893, 474; *Bacterium varicosus conjunctivae* Chester, Ann. Rept. Del. Col. Agr. Exp. Sta., *9*, 1897, 100; Migula, Syst. d. Bakt., *2*, 1900, 444.) From the normal conjunctiva of man.

Bacterium variosum Weiss. (Arb. bakt. Inst. Karlsruhe, *2*, Heft 3, 1902, 218.) From vegetable infusions.

Bacterium velatum Migula. (*Bacillus tuberigenus 5*, Gonnermann, Landwirtsch. Jahrb., *23*, 1894, 657; Migula, Syst. d. Bakt., *2*, 1900, 454; *Bacillus velatus* Nepveux, Thèse, Fac. Pharm., Paris, 1920, 113.) From lupine root nodules.

Bacterium vernicosum Zopf. (Zopf, Beitr. z. Physiol. u. Morphol. niederer Organismen, Heft 1, 1892, 63; *Bacillus vernicosus* Migula, Syst. d. Bakt., *2*, 1900, 781.) From cotton-seed meal.

Bacterium vesiculosum Henrici. (Arb. a. d. bakt. Inst. d. techn. Hochschule zu Karlsruhe, *1*, Heft, 1, 1894, 37.) From cheese.

Bacterium villosum (Keck) Migula. (*Bacillus villosus* Keck, Inaug. Diss., Dorpat, 1890, 47; Migula, Syst. d. Bakt., *2*, 1900, 429; *Plocamobacterium villosum* Pribram, Klassifikation der Schizomyceten, Leipzig und Wien, 1933, 79.) From water.

Bacterium vinicola Migula. (*Bacillus viscosus vini* Kramer, Bakteriol. in ihren Beziehungen z. Landwirtsch., *2*, 1892, 144; Migula, Syst. d. Bakt., *2*, 1900, 510.) From wine.

Bacterium viniperda Migula. (*Bacillus saprogenes vini IV*, Kramer, Bakteriol. in ihren Beziehungen z. Landwirtsch., *2*, 1892, 135; Migula, Syst. d. Bakt., *2*, 1900, 446.) From diseased wine.

Bacterium viride van Tieghem. (Bull. Soc. bot. France, *27*, 1880, 174.) Found on a fungus.

Bacterium viscidum Migula. (*Bacillus viscosus margarineus* Jolles and Winkler, Ztschr. f. Hyg., *20*, 1895, 104; Migula, Syst. d. Bakt., *2*, 1900, 450.) From margarine.

Bacterium viscosum Migula. (*Bacillus viscosus sacchari* Kramer, Sitzungsb. d. kais. Akad. d. Wiss., Wien, 1889; Bakteriol. in ihren Beziehungen z. Landwirtsch., *2*, 1892, 156; Migula, Syst. d. Bakt., *2*, 1900, 447.) Similar to *Leuconostoc mesenteroides* except that it liquefies gelatin.

Bacterium viscosum non-liquefaciens Stutzer and Wsorow. (Cent. f. Bakt., II Abt., *71*, 1927, 117.) From pupae of moth (*Euxoa segetum*). Resembles *Bacillus viscosus* Frankland.

Bacterium vitulinum Chester. (Bacillus der Septikämie bei einem Seekalbe, Bosso, Cent. f. Bakt., *25*, 1899, 52; Chester, Man. Determ. Bact., 1901, 143.) From a septicemia of the sea-calf (*Phoca vitulina*).

Bacterium vitulorum Migula. (Bacillus der weissen Ruhr der Kälber, Jensen, Monatsh. f. prakt. Tierheilk., *3*, 1892, 92; Maanedskrift for Dyrlaeger, *4*, 1892–93, 140; *Bacillus dysenteriae vitulorum* Kruse, in Flügge, Die Mikroorganismen, 3 Aufl., *2*, 1896, 412; *Bacterium dysenteriae vitulorum* Chester, Ann. Rept. Del. Col. Agr. Exp. Sta., *9*, 1897, 86; Migula, Syst. d. Bakt., *2*, 1900, 394; *Bacterium dysenteriae* Chester, Man. Determ. Bact., 1901, 145.) Associated with dysentery of calves.

Bacterium winkleri Migula. (Margarinbacillus *β*, Jolles and Winkler, Ztschr. f. Hyg., *20*, 1895, 102; Migula, Syst. d. Bakt., *2*, 1900, 485.) From margarine.

Bacterium wrightii Chester. (Capsule Bacillus of Mallory and Wright,

Ztschr. f. Hyg., *20*, 1895, 220; Chester, Man. Determ. Bact., 1901, 133.) From a case of bronchopneumonia.

Bacterium zinnioides Honing. (Cent. f. Bakt., II Abt., *37*, 1913, 371.) From tobacco, peanut and other plants in Sumatra.

Bacterium zuernianum (List) Chester. (*Bacillus zuernianus* List, Inaug. Diss., Leipzig, 1885, 36; Chester, Ann. Rept. Del. Col. Agr. Exp. Sta., *9*, 1897, 83.) From fresh manure and intestines of sheep; also found in water.

Coccobacillus acridiorum Picard and Blanc. (Coccobacille des sauterelles, d'Herelle, Compt. rend. Acad. Sci. Paris, *152*, 1911, 1413; Picard and Blanc, *ibid.*, *156*, 1913, 1335; *Bacillus acridiorum* Chatton, *ibid.*, *156*, 1913, 1708.) From a locust (*Schistocerca americana* Drury).

Coccobacillus cajae Picard and Blanc. (Compt. rend. Acad. Sci., Paris, *156*, 1913, 1334; *Bacillus cajus* Marchol, Revue de Phytopath. Appl., *1*, 1914, 11.) From diseased caterpillars of *Arctia caja*.

Coccobacillus gibsoni Chorine. (Internat. Corn Borer Invest., Sci. Repts., *2*, 1929, 42; *B. gibsoni* Paillot, *B.* presumably indicates *Bacterium*, see index, p. 522, L'infection chez les insectes, 1933, 134; *Bacillus gibsoni* Steinhaus, Bacteria Associated Extracellularly with Insects, Minneapolis, 1942, 58.) From diseased corn borer larvae (*Pyraustra nubilalis*).

Coccobacillus insectorum Hollande and Vernier. (Compt. rend. Acad. Sci., Paris, *171*, 1920, 207.) From diseased caterpillars of a moth (*Malacosoma castrensis*).

Coccobacillus insectorum var. *malacosomae* Hollande and Vernier. (Compt. rend. Acad. Sci., Paris, *171*, 1920, 208.) From diseased caterpillars of a moth (*Malacosoma castrensis*).

Denitrobacterium thermophilum Ambroz. (Cent. f. Bakt., II Abt., *37*, 1913, 3.) A thermophilic bacterium from soil.

Diplobacillus melolonthae Paillot. (Compt. rend. Soc. Biol., Paris, *69*, 1917, 5; Annales des Épiphyties, *8*, 1922, 117.) From larvae of cockchafers (*Melolontha melolontha*).

Diplobacillus pieris Paillot. (Annales des Épiphyties, *8*, 1922, 129.) From diseased caterpillars of the cabbage butterfly (*Pieris brassicae*).

Helicobacterium aerogenes Miller. (Deutsche Med. Wchnschr., *12*, 1886, 119; *Bacillus helicoides* DeToni and Trevisan, in Saccardo, Sylloge Fungorum, *8*, 1889, 952.) From the stomach. This is the type species of the genus *Helicobacterium*.

Helicobacterium klebsii Miller. (Die Mikroorganismen der Mundhöhle, 2 Aufl., Leipzig, 1892, 370; quoted from Buchanan, Gen. Syst. Bact., Baltimore, 1925, 327.) From the mouth.

Microbacillus citreus baregensis Robine and Hauduroy. (Compt. rend. Soc. Biol., Paris, *98*, 1928, 26.) From hot sulfur springs at Barèges. Fourment (Compt. rend. Soc. Biol., Paris, *98*, 1928, 588) states that this species is *Bacillus luteus* Flügge, but Robine and Hauduroy (Compt. rend. Soc. Biol., Paris, *99*, 1928, 317) deny this.

Micrococcobacillus necroticans Pascheff. (See Pascheff, Bericht. d. ophthalmol. Gesellsch., Heidelberg, 1916, 418 or Klin. Monatsbl. f. Augenheilk., *57*, 1916, 517 and *58*, 1917, 97; *Coccobacillus polymorphus necroticans*, quoted from Bayer and v. Herrenschwand, Arch. f. Ophthalmol., *98*, 1919, 358; *Micrococcobacillus polymorphus necroticans* Pascheff, Arch. d'Ophthalmol., *38*, 1921, 28; Pascheff, *ibid.*, 97.) From the human eye. Reported as the causal organism of conjunctivitis.

Nitrosobacillus thermophilus Campbell. (Sci., *75*, 1932, 23.) From soil. Oxidizes ammonia to nitrite.

Pacinia ferrarii Trevisan. (Bacillo dell' ulcera molle, Ferrari, 1885; Trevisan, I generi e le specie delle Batteriacee, 1889, 23.)

Pacinia fickii Trevisan. (Bacillus e des Conjunctivalsackes, Fick, 1887; Trevisan, I generi e le specie delle Batteriacee, 1889, 23.)

Pacinia micheli Trevisan. (Michel, Luftstäbchen des Conjunctivalsecretes, 1882; Trevisan, I generi e le specie delle Batteriacee, 1889, 23.) From the conjunctiva.

Plocamobacterium acidi lactici Pribram. (Lange Milchsaurestäbchen, Wolff, Cent. f. Bakt., II Abt., *20*, 1908, 545; Pribram, Klassifikation der Schizomyceten, Leipzig und Wien, 1933, 76.) From milk.

Plocamobacterium epidermidis (Bizzozero) Pribram. (*Leptothrix epidermidis* Bizzozero, Arch. f. path. Anat., *98*, 1896, 455; Pribram, *loc. cit.*, 77.) From the skin.

Plocamobacterium proteolyticum (Wollman) Pribram. (*Glycobacter proteolyticus* Wollman, Ann. Inst. Past., *26*, 1912, 617; Pribram, *loc. cit.*, 118.)

Plocamobacterium rubrum Pribram, *loc. cit.*, 78. Red cheese bacterium (Kiel).

Plocamobacterium tilsitense Pribram, *loc. cit.*, 78. From Tilsit cheese (Kiel).

Proteus hominis Bordoni-Uffreduzzi. (Bacterium, Bordoni-Uffreduzzi and Di Mattei, Arch. per le scienze mediche, *10*, 1886, No. 7; abst. in Cent. f. Bakt., *1*, 1887, 345; Bordoni-Uffreduzzi, Ztschr. f. Hyg., *3*, 1888, 333; *Proteus hominis capsulatus* Bordoni-Uffreduzzi, *ibid.*; *Proteus capsulatus septicus* Banti, Lo Sperimentale, *88*; *Klebsiella bordonii* Trevisan, I generi e le specie delle Batteriacee, 1889, 25; *Bacillus capsulatus septicus* Kruse, in Flügge, Die Mikroorganismen, 3 Aufl., *2*, 1896, 345; *Bacterium hominis capsulatus* Chester, Ann. Rept. Del. Col. Agr. Exp. Sta., *9*, 1897, 136; *Bacterium capsulatus* and *Bacterium capsulatus septicus* Chester, *ibid.*, 130; *Bacterium proteus* Migula, Syst. d. Bakt., *2*, 1900, 362; *Bacterium bordonii* Chester, Manual of Determ. Bact., 1901, 152.) From a case of ragpicker's disease which may have been anthrax or malignant edema.

Urobacillus beijerinckii Christensen. (Christensen, Cent. f. Bakt., II Abt., *27*, 1910, 357; *Bacillus beijerinckii* De Rossi, Microbiologia Agraria e Technica, 1927, 646.) From humus. Utilizes urea.

Urobacillus jakschii Söhngen. (Söhngen, Cent. f. Bakt., II Abt., *23*, 1909, 93; *Bacillus jakschii* De Rossi, Microbiologia Agraria e Technica, 1927, 646.) From garden earth. Utilizes urea.

Urobacillus miquelii Beijerinck. (Cent. f. Bakt., *7*, 1901, 47.) From garden earth. Löhnis (Handb. f. landwirtsch. Bakt., 1910, 459) regards this as belonging to the genus *Proteus*.

Urobacillus schützenbergii I and *II* Miquel. (Miquel, Ann. de Micrograph., *5*, 1893, 321 and 323; *Bacillus schützenbergii* Migula, Syst. d. Bakt., *2*, 1900, 727.) From sewage and river water. These may belong to *Proteus* (Löhnis, Handb. f. landwirtsch. Bakt., 1910, 459).

Urobacterium aerophilum Rubentschik. (Cent. f. Bakt., II Abt., *66*, 1925, 175.) From salt water, Lake Liman near Odessa.

Urobacterium citrophilum Rubentschik. (Cent. f. Bakt., II Abt., *66*, 1925, 172.) From black mud and salt water, Lake Liman near Odessa.

Viscobacterium lactis foetidum Laxa. (Cent. f. Bakt., II Abt., *95*, 1936, 130.) From milk having a fetid odor.

APPENDIX TO SUBORDER EUBACTERIINEAE

Record of species and synonyms discovered too late to be entered in the main body of the text. Arranged alphabetically by genera.

Acetobacter aceti (Kützing) Beijerinck syn. *Bacterium aceticus* Chester, Ann. Rept. Del. Col. Agr. Exp. Sta., *9*, 1897, 77.

Acetobacter acetosum Bergey et al. syn. *Ulvina acetosa* Pribram, Klassifikation der Schizomyceten, Leipzig und Wien, 1933, 75.

Acetobacter ascendens Bergey et al. syn. *Ulvina ascendens* Pribram, Klassifikation der Schizomyceten, Leipzig und Wien, 1933, 75.

Acetobacter diversum Humm. (Duke Univ. Marine Lab., North Carolina, Bull. 3, 1946, 63.) From sea water, Beaufort, North Carolina and marine algae, Miami, Florida. Digests agar.

Acetobacter mobile Tŏsić and Walker. (Jour. of Brewing, *50*, 1944, 296.) From bottled ale.

Acetobacter pasteurianum (Hansen) Beijerinck syn. *Bacillus pasteurianum* Flügge, Die Mikroorganismen, 2 Aufl., 1886, 314; not *Bacillus pasteurianus* Lehmann and Neumann, Bakt. Diag., 4 Aufl., *2*, 1907, 82; *Ulvina pasteuriana* Pribram, Klassifikation der Schizomyceten, Leipzig und Wien, 1933, 76.

Acetobacter potens Humm. (Duke Univ. Marine Lab., North Carolina, Bull. 3, 1946, 63.) From intertidal sand, Beaufort, North Carolina. Digests agar.

Acetobacter rancens Beijerinck syn. *Ulvina rancens* Pribram, Klassifikation der Schizomyceten, Leipzig und Wien, 1933, 76.

Acetobacter singulare Humm. (Duke Univ. Marine Lab., North Carolina, Bull. 3, 1946, 62.) From sea water, Beaufort, North Carolina. Digests agar.

Acetobacter xylinum (Brown) Holland syn. *Bacillus xylinus* Trevisan, I generi e le specie delle Batteriacee, 1889, 16; *Ulvina xylina* Pribram, Klassifikation der Schizomyceten, Leipzig und Wien, 1933, 76.

Achromobacter caseinicum Gahl. (Jour. Bact., *16*, 1928, 38.) From a solution of sodium caseinate. Polar flagellate. Possibly a strain of *Pseudomonas fluorescens* Migula that had lost the power of forming pigment.

Achromobacter nijibetsui Takeda. (Cent. f. Bakt., II Abt., *94*, 1936, 48.) From diseased salmon eggs. Not found to be virulent. A polar-flagellated, Gram-negative, yellow chromogen, presumably belonging in the genus *Xanthomonas*.

Actinobacillus actinomycetemcomitans Topley and Wilson syn. *Bacillus actinomycetemcomitans* Rosebury, Bact. Rev., *8*, 1944, 205.

Aerobacter liquefaciens Beijerinck. (Cent. f. Bakt., II Abt., *6*, 1900, 199; not *Aerobacter liquefaciens* Grimes and Hennerty, Sci. Proc. Roy. Dublin Soc., (N.S.) *20*, 1931, 93.) From mud and water in swamps. Monotrichous, otherwise like *Aerobacter cloacae*. This may have been a species of gas-forming *Pseudomonas*.

Aerobacter tartarivorum Nijdam. (Thesis, Leiden, 1907.) Decomposes d-tartrates. Probably identical with *Aerobacter aerogenes* (Vaughn, Marsh, Stadtman and Cantino, Jour. Bact., *52*, 1946, 324).

Alcaligenes marshallii Bergey et al. syn. *Bacterium marshalli* Buchanan and Hammer, Iowa Sta. Coll. Agr. Exp. Sta., Res. Bull. 22, 1915, 272.

Alcaligenes viscosum Weldin syn. *Plocamobacterium viscosum* Pribram, Klassifikation der Schizomyceten, Leipzig und Wien, 1933, 79.

Ascococcus buccalis Miller. (Die Mikroorganismen der Mundhöhle, Leipzig, 1889, 65.) From the mouth.

Bacillus annulatus Wright Syn. *Bacterium annulatus* Chester, Ann. Rept. Del. Col. Agr. Exp. Sta., *9*, 1897, 105.

Bacillus cubonianus Macchiati syn. *Bacterium cubonianus* Chester, Ann. Rept. Del. Col. Agr. Exp. Sta., *9*, 1897, 132.

Bacillus duplicatus Wright. (Wright, Mem. Nat. Acad. Sci., *7*, 1895, 457; *Bacterium duplicatus* Chester, Ann. Rept. Del. Col. Agr. Exp. Sta., *9*, 1897, 90.) From Schuylkill River water. Monotrichous.

Bacillus fluorescens mutabilis Wright. (Wright, Mem. Nat. Acad. Sci., *7*, 1895, 449; *Bacterium fluorescens mutabilis* Chester, Ann. Rept. Del. Col. Agr. Exp. Sta., *9*, 1897, 120.) From Schuylkill River water.

Bacillus fluorescens nivalis Eisenberg syn. *Bacterium fluorescens nivalis* Chester, Ann. Rept. Del. Col. Agr. Exp. Sta., *9*, 1897, 120.

Bacillus haydocki Henneberg syn. *Plocamobacterium haydocki* Pribram, Klassifikation der Schizomyceten, Leipzig und Wien, 1933, 77.

Bacillus influenzoides apis White. (Jour. Path. and Bact., *24*, 1921, 71.) From intestine of bee. Monotrichous.

Bacillus mesentericus aureus Winkler syn. *Bacillus winkleri* Chester, Man. Determ. Bact., 1901, 256.

Bacillus pabuli acidi II Weiss syn. *Plocamobacterium pabuli* Pribram, Klassifikation der Schizomyceten, Leipzig und Wien, 1933, 78.

Bacillus vaginae Kruse syn. *Bacterium vaginae* Chester, Ann. Rept. Del. Col. Agr. Exp. Sta., *9*, 1897, 67.

Bacillus viridi-luteus Trevisan. (Grüngelber Bacillus, Eisenberg, Bakt. Diag., 1 Aufl., 1886, 10; Trevisan, I generi e le specie delle Batteriacee, 1889, 19.) From water. This probably was the same as *Bacillus fluorescens* Trevisan, *ibid.*, 19 and *Pseudomonas fluorescens* Migula.

Bacillus wortmannii Henneberg syn. *Plocamobacterium wortmanni* Pribram, Klassifikation der Schizomyceten, Leipzig und Wien, 1933, 79.

Bacterium granulosum Lehmann and Neumann syn. *Plocamobacterium granulosum* Pribram, Klassifikation der Schizomyceten, Leipzig und Wien, 1933, 77.

Bacterium lipolyticum Huss syn. *Kurthia lipolyticum* Pribram, Klassifikation der Schizomyceten, Leipzig und Wien, 1933, 75.

Bacterium orleanense Henneberg syn. *Ulvina orleanensis* Pribram, Klassifikation der Schizomyceten, Leipzig und Wien, 1933, 75.

Bacterium xylinoides Henneberg syn. *Ulvina xylinoides* Pribram, Klassifikation der Schizomyceten, Leipzig und Wien, 1933, 76.

Brucella byzantinea (Montsouris) Pribram. (*Coccobacterium byzantineum* Montsouris, quoted from Pribram, Klassifikation der Schizomyceten, Leipzig und Wien, 1933, 67; Pribram, *idem.*)

Brucella cocciformis (Jaiser) Pribram. (*Bacterium cocciforme* Jaiser, quoted from Pribram, Klassifikation der Schizomyceten, 1933, 67; *Coccobacterium thermophilum* Negre, Compt. rend. Soc. Biol., Paris, *75*, 1913, 814 and 867; Pribram, *idem.*) From sputum.

Chlorobacterium lactis Guillebeau. (Landw. Jahrb. d. Schweiz., *4*, 1890, 32.) From the udder of cows with mastitis. Produces a green pigment. Presumably identical with *Pseudomonas aeruginosa* Migula. The type species of the genus *Chlorobacterium* Guillebeau.

Chromobacterium chocolatum Knutsen. (Quoted from Lasseur, Dupaix-Lasseur and Melcion, Travaux du Lab. de Microbiol., Fac. Pharm. de Nancy, Fasc. XIII, 1942–43–44, 1944, 164, 187, 293, and 313.) Isolated by M. H. Knutsen, State Coll., Pennsylvania. Source not known. Dull violet with brown tinge. Disso-

ciates into a violet and an orange strain (*Chromobacterium orangium* Knutsen, *loc. cit.*, 294).

Chromobacterium iodinum Davis. (Davis, Cent. f. Bakt., II Abt., *100*, 1939, 273; also see Clemo and McIlwain, Jour. Chem. Soc., Pt. 1, 1938, 479; *Pseudomonas iodinum* Tobie and *Pseudomonas clemo* Tobie, Bull. Assoc. des Diplômés de Microbiol., Fac. Pharm. Nancy, No. 18, 1939, 16.) From plate inoculated with milk. This non-motile organism does not have the characters of *Chromobacterium* sensu stricto so that this species is retained with *Bacterium* for the present.

Coccus cumulus minor Black. (Trans. Ill. State Dental Soc., *22*, 1886, 192.) From the mouth.

Corynebacterium hemolyticum MacLean, Liebow and Rosenberg. (Jour. Inf. Dis., *79*, 1946, 69.) From infections among American soldiers and natives in the South and West Pacific. Similar in many ways to *Corynebacterium pyogenes* and *C. ovis*.

Corynebacterium piriforme Honing. (Cent. f. Bakt., II Abt., *37*, 1913, 383.) From tobacco plants in Sumatra.

Diplococcus aquatilis Vaughan. (Amer. Jour. Med. Sci., *104*, 1892, 184.) From water.

Diplococcus glycinophilus Cardon and Barker. (Jour. Bact., *52*, 1946, 629.) From marine mud.

Diplococcus luteus Adametz and Wichmann. (Adametz and Wichmann, Die Bakterien der Trink- und Nutzwässer, Mitt. Oest. Versuchsstat. f. Brauerei u. Mälzerei, Heft 1, 1888, 49; *Planococcus luteus* Migula, Syst. Bakt., *2*, 1900, 274.) From water.

Escherichia Castellani and Chalmers syn. *Colibacter* Pestana and Andrade, Ann. Paulistas de Med. e Cir., *39*, 1940, 462.

Escherichia coli Castellani and Chalmers syn. *Colibacter commune* Pestana and Andrade, *loc. cit.*

Flavobacterium harrisonii Bergey et al. syn. *Bacillus harrisonii* Buchanan and Hammer, Iowa Sta. Coll. Agr. Exp. Sta., Res. Bull. 22, 1915, 257.

Flavobacterium tabidum Kimata. (Cent. f. Bakt., II Abt., *105*, 1942, 120.) From spoiled semi-dried fish (*Trachurus japonicus*). Polar flagellate.

Fusiformis grandis Grassé. (Compt. rend. Soc. Biol., Paris, *94*, 1926, 1014; Arch. Zool. Expér. et Gén., *65*, 1926, 463.) From the surface of the body of a flagellate (*Polymastix melolonthae*), in the intestine of larvae of beetles and tipulids, possibly also free in the intestine of the insects.

Fusiformis legeri Grassé. (Compt. rend. Soc. Biol., Paris, *94*, 1926, 1014; Arch. Zool. Expér. et Gén., *65*, 1926, 467.) From the surface of the body of a flagellate (*Polymastix legeri*) and in the intestine of diplopods.

Fusiformis lophomonadis Grassé. (Compt. rend. Soc. Biol., Paris, *94*, 1926, 1015; Arch. Zool. Expér. et Gén., *65*, 1926, 468.) From the surface of the body of a flagellate (*Lophomonas striata*) and in the intestine of cockroaches.

Fusiformis melolonthae Grassé. (Compt. rend. Soc. Biol., Paris, *94*, 1926, 1014; Arch. Zool. Expér. et Gén., *65*, 1926, 465.) From the surface of the body of a flagellate (*Polymastix melolonthae*) and in the intestine of larvae of beetles and tipulids.

Gluconoacetobacter cerinus Takahashi and Asai. (Cent. f. Bakt., II Abt., *93*, 1936, 252.) From fruits.

Gluconoacetobacter liquefaciens Takahashi and Asai, *loc. cit.* From fruits.

Gluconoacetobacter roseus Takahashi and Asai. (*Bacterium industrium* var. *hoshigaki* Takahashi and Asai, Cent. f. Bakt., II Abt., *82*, 1930, 400; *Bacterium hoshigaki* var. *glucuronicum I* Takahashi and Asai, *ibid.*, *87*, 1933, 385; Takahashi and Asai, *ibid.*, *93*, 1936, 252.) From dried persimmons (hoshigaki).

Gluconobacter liquefaciens Asai. (Jour. Agr. Chem. Soc. Japan, *10*, 1934,

621 and *11*, 1935, 50; see Cent. f. Bakt., II Abt., *93*, 1936, 248.) From fruits.

Jodococcus magnus Miller. (Deutsche med. Wchnschr., *14*, 1888, 612.) From the mouth. The type species of the genus *Jodococcus* (syn. *Iodococcus*) Miller.

Jodococcus parvus Miller (*ibid.*, 612). From the mouth.

Lactobacillus bulgaricus Holland syn. *Bacterium bulgaricum* Buchanan and Hammer, Iowa Sta. Agr. Exp. Sta., Res. Bull. 22, 1915, 250.

Lactobacillus buchneri Bergey et al. syn. *Ulvina buchneri* Pribram, Klassifikation der Schizomyceten, Leipzig und Wien, 1933, 75.

Lactobacillus delbrueckii Beijerinck syn. *Ulvina delbruecki* Pribram, *loc. cit.*, 75; *Plocamobacterium delbruecki* Pribram, *ibid.*, 77.

Lactobacillus helveticus Holland syn. *Plocamobacterium casei* Pribram, *loc. cit.*, 77; *Plocamobacterium helveticum* Pribram, *ibid.*, 78.

Lactobacillus pastorianus Bergey et al. syn. *Plocamobacterium pastorianum* Pribram, *loc. cit.*, 78.

Lactobacillus pentoaceticus Fred, Peterson and Davenport syn. *Plocamobacterium pentoaceticum* Pribram, *loc. cit.*, 78.

Lactobacillus plantarum Holland syn. *Ulvina cucumeris fermentati* Pribram, *loc. cit.*, 75.

Lactobacillus taette Olsen-Sopp. (Cent. f. Bakt., II Abt., *33*, 1912, 14.) From ropy milk.

Leptotrichia Trevisan partial syn. *Leucothrix* Oersted, De regionibus marinis, 1844, 44.

Listeria monocytogenes Pirie syn. *Brucella monocytogenes* Pribram, Klassifikation der Schizomyceten, Leipzig und Wien, 1933, 68.

Mammococcus gorini. (Quoted from L. Gorini, Enzymologia, *10*, 1942, 102.) From the udder.

Micrococcus afermentans Castellani. (Proc. Soc. Exp. Biol. and Med., *25*, 1928, 536; also see Jour. Trop. Med. and Hyg., *35*, 1932, 372.) From an ulcerative lesion of the skin.

Micrococcus albus var. *maltigenes* Dumais and Albert. (Quebec Laitier, *5* (2), 1946, 19.) From Richelieu cheese. Regarded as an important ripening agent.

Micrococcus aquatilis Vaughan. (Vaughan, Amer. Jour. Med. Sci., *104*, 1892, 190; not *Micrococcus aquatilis* Chester, Man. Determ. Bact., 1901, 88; not *Micrococcus aquatilis* Bolton, Ztschr. f. Hyg., *1*, 1886, 94.) From water.

Micrococcus aquatilis albissimus von Rigler. (Hyg. Rund., *12*, 1902, 482.) From bottled mineral waters.

Micrococcus aquatilis albus Vaughan. (Vaughan, Amer. Jour. Med. Sci., *104*, 1892, 182; not *Micrococcus aquatilis albus* Toporoff, Cent. f. Bakt., *13*, 1893, 487.) From water.

Micrococcus aquatilis magnus Vaughan. (Amer. Jour. Med. Sci., *104*, 1892, 182.) From water.

Micrococcus aquivivus ZoBell and Upham. (Bull. Scripps Inst. of Oceanography, Univ. Calif., *5*, 1944, 275.) From sea water.

Micrococcus cyaneus (Schroeter) Cohn syn. *Bacterium cyaneus* White, U. S. D.A., Bur. Entomol. Tech. Ser. Bull. 14, 1906, 16.

Micrococcus enteroideus Castellani. (Proc. Soc. Exp. Biol. and Med., *25*, 1928, 536; also see Jour. Trop. Med. and Hyg., *35*, 1932, 372.) From feces.

Micrococcus euryhalis ZoBell and Upham. (Bull. Scripps Inst. of Oceanography, Univ. Calif., *5*, 1944, 255.) From sea water.

Micrococcus griseus Winter syn. *Bacillus griseus* Trevisan, I generi e le specie delle Batteriacee, 1889, 18.

Micrococcus himonoi Kimata. (Cent. f. Bakt., II Abt., *105*, 1942, 116.) From spoiled semi-dried fishes (*Scomber japonicus* and *Trachurus japonicus*). Resembles *Micrococcus caseolyticus* and *M. mucofaciens*.

Micrococcus infimus ZoBell and Upham. (Bull. Scripps Inst. of Oceanography, Univ. Calif., *5*, 1944, 262.) From marine bottom deposits.

Micrococcus laevulosinertis Castellani. (Proc. Soc. Exp. Biol. and Med., *25*, 1928, 536; also see Jour. Trop. Med. and Hyg., *35*, 1932, 372.) From a case of stomatitis.

Micrococcus maripuniceus ZoBell and Upham. (Bull. Scripps Inst. of Oceanography, Univ. Calif., *5*, 1944, 264.) Sessile form found on slides submerged in sea water.

Micrococcus metentericus Castellani. (Quoted from Jour. Trop. Med. and Hyg., *35*, 1932, 372.) From case of ulcerative colitis.

Micrococcus moricolor Holmes and Wilson. (Jour. Bact., *49*, 1945, 311.) From contaminated wounds. Produces a mulberry pigment on potato.

Micrococcus myceticus Castellani. (Arch. Dermat. and Syphil., *18*, 1928, 857.) From cases of pseudomycosis.

Micrococcus nexifer Miller. (Miller, Die Mikroorganismen der Mundhöhle, Leipzig, 1889, 65.) From the mouth. Probably *Streptococcus brevis* according to Goadby (Mycology of the Mouth, London, 1903, 60).

Micrococcus putatus Ravenel. (Mem. Nat. Acad. Sci., *8*, 1896, 21.) From soil.

Micrococcus putneus Castellani. (Quoted from Jour. Trop. Med. and Hyg., *35*, 1932, 372.) From a case of glossitis.

Micrococcus rhodochrous Migula syn. *Bacillus rhodochrous* Dyar, Ann. N. Y. Acad. Sci., *8*, 1895, 362; *Bacterium rhodochrous* Chester, Ann. Rept. Del. Col. Agr. Exp. Sta., *9*, 1897, 116.) Dyar had the original *Micrococcus rhodochrous* culture from Kràl and felt as have others who have examined this culture that it is not a true *Micrococcus*.

Micrococcus sedentarius ZoBell and Upham. (Bull. Scripps Inst. of Oceanography, Univ. Calif., *5*, 1944, 260.) Sessile form found on slides submerged in sea water.

Micrococcus sedimenteus ZoBell and Upham. (Bull. Scripps Inst. of Oceanography, Univ. Calif., *5*, 1944, 265.) Sessile form found on slides submerged in sea water and in marine mud.

Micrococcus visicidus Castellani. (Proc. Soc. Exp. Biol. and Med., *25*, 1928, 536; also see Jour. Trop. Med. and Hyg., *35*, 1932, 372.) From an inflamed upper lip.

Microspira vacillans Gicklhorn. (Cent. f. Bakt., II Abt., *50*, 1920, 422.) From the pool in the Botanical Garden, Univ. Graz, Austria. Contains grains of sulfur.

Neisseria babesi Trevisan. (Bactérie de l'hémoglobinurie du boeuf, Babes, 1888; Trevisan, I generi e le specie delle Batteriacee, 1889, 32.)

Neisseria lutea (Adametz) Trevisan. (*Diplococcus luteus* Adametz, 1887; Trevisan, I generi e le specie delle Batteriacee, 1889, 32.)

Neisseria micheli Trevisan. (Trachomcoccus, Michel, 1886; Trevisan, I generi e le specie delle Batteriacee, 1889, 32.)

Neisseria pharyngis syn. *Micrococcus pharyngis* Cruikshank and Cruikshank, Med. Res. Council Syst. of Bact., *8*, 1931, 349.

Pacinia decipiens Trevisan. (*Spirillum* aus der Luft, Babes, Ztschr. f. Hyg., *5*, 1888, 183; Trevisan, I generi e le specie delle Batteriacee, 1889, 24.) From the air.

Pacinia rabida Trevisan. (Spirillum bei Rabies, Babes, Ztschr. f. Hyg., *5*, 1888, 181; Trevisan, I generi e le specie delle Batteriacee, 1889, 23.)

Pectobacterium delphinii Waldee. (Ark, Phytopath., *28*, 1938, 281; Waldee, Iowa State Coll. Jour. Sci., *19*, 1945, 471.) Causes larkspur bacterial blight.

Phytomonas asplenii Ark and Tompkins. (Phytopath., *36*, 1946, 760.) Causes leaf blight of bird's nest fern.

Phytomonas maculifolium-gardeniae

Ark. (Phytopath., *36*, 1946, 867.) From gardenia (*Gardenia jasminoides*). A xanthomonad.

Phytomonas syringae populans Smith. (Jour. Agr. Res., *68*, 1944, 269.) Considered the cause of blister spot, a disease of apple.

Phytomonas washingtoniae Pine. (Phytopath., *33*, 1943, 1203.) From the Washington palm, *Washingtonia filifera*. A pseudomonad.

Pneumococcus flavescens Arloing. (Compt. rend. Acad. Sci., *109*, 1889, 428 and 459.) From lesions of cattle having peripneumonia.

Pneumococcus gutta cerei Arloing, *loc. cit.* From lesions of cattle having peripneumonia.

Pneumococcus lichnoides Arloing, *loc. cit.* From lesions of cattle having peripneumonia.

Pseudomonas aestumarina ZoBell and Upham. (Bull. Scripps Inst. of Oceanography, Univ. Calif., *5*, 1944, 269.) A marine sedentary organism.

Pseudomonas allii (Griffiths) Migula syn. *Bacillus allii* Sternberg, Man. of Bact., 1893, 629.

Pseudomonas ambigua (Wright) Chester syn. *Bacterium ambiguus* Chester, Ann. Rept. Del. Col. Agr. Exp. Sta., *9*, 1897, 71.

Pseudomonas atlantica Humm. (Duke Univ. Marine Lab., North Carolina, Bull. 3, 1946, 58.) From seaweed (*Gracilaria blodgettii*) and beach sand. Digests agar.

Pseudomonas aurea Migula syn. *Bacterium fluorescens aureus* Chester, Ann. Rept. Del. Col. Agr. Exp. Sta., *9*, 1897, 109.

Pseudomonas azotogena ZoBell and Upham. (Bull. Scripps Inst. of Oceanography, Univ. Calif., *5*, 1944, 260.) From sea water and marine mud.

Pseudomonas beaufortensis Humm (*loc. cit.*, 58). From seawater, bottom mud and on algae. Digests agar.

Pseudomonas berolinensis Migula. (Indigoblauer Bacillus, Claessen, Cent. f. Bakt., *7*, 1890, 13; *Bacillus berolinensis indicus* Germano, Cent. f. Bakt., *12*, 1892, 517; *Bacillus indigoferus* Zimmermann, Bakt. unserer Trink- u. Nutzwässer, Chemnitz, *2*, 1894, 16, not indicated as being the same as *Bacillus indigoferus* Voges, Cent. f. Bakt., *14*, 1893, 307; *Bacillus indigonaceus* Schneider, Arb. bakt. Inst. Karlsruhe, *1*, Heft 2, 1894, 228; Migula, in Engler and Prantl, Die natürl. Pflanzenfam., *1*, 1a, 1895, 29; *Bacterium indigonaceum* Lehmann and Neumann, Bakt. Diag., 1 Aufl., *2*, 1896, 267; *Bacterium berolinensis indicus* Chester, Ann. Rept. Del. Col. Agr. Exp. Sta., *9*, 1897, 118.) From Spree River water.

Pseudomonas butyri Migula syn. *Bacterium butyri fluorescens* Chester, Ann. Rept. Del. Col. Agr. Exp. Sta., *9*, 1897, 120.

Pseudomonas centrifugans (Wright) Chester. (*Bacillus centrifugans* Wright, Mem. Nat. Acad. Sci., *7*, 1895, 462; *Bacterium centrifugans* Chester, Ann. Rept. Del. Col. Agr. Exp. Sta., *9*, 1897, 95; Chester, Man. Determ. Bact., 1901, 312.) From water.

Pseudomonas coadunata Chester syn. *Bacterium coadunatus* Chester, Ann. Rept. Del. Col. Agr. Exp. Sta., *9*, 1897, 90.

Pseudomonas coenobios ZoBell and Upham. (Bull. Scripps Inst. of Oceanography, Univ. Calif., *5*, 1944, 272.) From film of marine fouling organisms.

Pseudomonas cohaerea (Wright) Chester, not *Bacillus cohaerens* Gottheil, Cent. f. Bakt., II Abt., *7*, 1901, 458; *Bacterium cohaereus* (sic) Chester, Ann. Rept. Del. Col. Agr. Exp. Sta., *9*, 1897, 93.

Pseudomonas coli communis Conn, Esten and Stocking. (Storrs Agri. Exp. Sta., Conn., 18th Ann. Rept. for 1906, 186.) From cheddar cheese. Like *Bacillus coli communis* except that it has a single, long flagellum.

Pseudomonas convexa Chester syn. *Bacterium fluorescens convexus* Chester,

Ann. Rept. Del. Col. Agr. Exp. Sta., *9*, 1897, 123.

Pseudomonas corallina Humm (*loc. cit.*, 59). From marine algae of all common species at Beaufort, Nor. Car. Digests agar.

Pseudomonas delabens (Wright) Chester syn. *Bacterium delabens* Chester, Ann. Rept. Del. Col. Agr. Exp. Sta., *9*, 1897, 97.

Pseudomonas eisenbergii Migula syn. *Bacterium fluorescens non-liquefaciens* Chester, Ann. Rept. Del. Col. Agr. Exp. Sta., *9*, 1897, 124.

Pseudomonas elongata Humm (*loc. cit.*, 60). From intertidal sand, Atlantic Beach, Nor. Car. Digests agar.

Pseudomonas enalia ZoBell and Upham. (Bull. Scripps Inst. of Oceanography, Univ. Calif., *5*, 1944, 254.) From sea water and marine mud.

Pseudomonas fairmountensis (Wright) Chester syn. *Bacterium fairmountensis* Chester, Ann. Rept. Del. Col. Agr. Exp. Sta., *9*, 1897, 90.

Pseudomonas felthami ZoBell and Upham. (Bull. Scripps Inst. of Oceanography, Univ. Calif., *5*, 1944, 267.) From marine mud.

Pseudomonas fimbriata (Wright) Chester syn. *Bacterium fimbriatus* Chester, Ann. Rept. Del. Col. Agr. Exp. Sta., *9*, 1897, 95.

Pseudomonas floridana Humm (*loc. cit.*, 60). From algae and beach sand at Miami, Fla., and Beaufort, Nor. Car. Digests agar.

Pseudomonas fluorescens Migula syn. *Bacterium fluorescens liquefaciens* Chester, Ann. Rept. Del. Col. Agr. Exp. Sta., *9*, 1897, 120.

Pseudomonas foliacea Chester syn. *Bacterium fluorescens foliaceus* Chester, Ann. Rept. Del. Col. Agr. Exp. Sta., *9*, 1897, 122.

Pseudomonas geniculatus (Wright) Chester. *Bacillus geniculatus* Wright; not *Bacillus geniculatus* DeBary, Inaug. Diss., Strassburg, Leipzig, 1885; not *Bacillus geniculatus* Trevisan, I generi e le specie delle Batteriacee, 1889, 16; syn. *Bacterium geniculatus* Chester, Ann. Rept. Del. Col. Agr. Exp. Sta., *9*, 1897, 95.

Pseudomonas humicola Bersteyn. (Arb. bakt. Inst. Karlsruhe, *3*, 1903, 97.) From soil.

Pseudomonas hypothermis ZoBell and Upham. (Bull. Scripps Inst. of Oceanography, Univ. Calif., *5*, 1944, 276.) From marine bottom deposits.

Pseudomonas incognita Chester syn. *Bacterium fluorescens incognitus* Chester, Ann. Rept. Del. Col. Agr. Exp. Sta., *9*, 1897, 122.

Pseudomonas indoloxidans Gray. (Proc. Roy. Soc. London, B, *102*, 1928, 263.) From soil from Italian Tyrol.

Pseudomonas indigoferus (Voges) Migula. (*Bacillus indigoferus* Voges, Cent. f. Bakt., *14*, 1893, 307; *Bacterium indigoferus* Chester, Ann. Rept. Del. Col. Agr. Exp. Sta., *9*, 1897, 118; Migula, Syst. d. Bakt., *2*, 1900, 950.) From Kiel tap water (Voges); from Delft ditch water, mud and garden soil (Elazari-Volcani, Arch. f. Mikrobiol., *10*, 1939, 357). Some authors regard Voges' organism as identical with Claessen's indigo blue bacillus, see *Pseudomonas berolinensis*.

Pseudomonas indigoferus var. *immobilis* Elazari-Volcani. (Arch. f. Mikrobiol., *10*, 1939, 350.) From ditch mud. See Lehmann and Neumann (Bakt. Diag., 1 Aufl., *2*, 1896, 267) who also had a non-motile strain (*Bacterium indigonaceum*) from Kràl which they considered identical with Claessen's indigo blue bacillus.

Pseudomonas inertia Humm (*loc. cit.*, 61). From intertidal sand, Atlantic Beach, Nor. Car. Digests agar.

Pseudomonas iris Migula syn. *Bacillus fluorescens crassus* Kruse, in Flügge, Die Mikroorganismen, 3 Aufl., *2*, 1896, 294; *Bacterium fluorescens crassus* Chester, Ann. Rept. Del. Col. Agr. Exp. Sta., *9*, 1897, 134; *Bacterium iris* Chester, *idem*, 137.) From sputum.

Pseudomonas jaegeri Migula syn. *Bac-*

terium proteus fluorescens Chester, Ann. Rept. Del. Col. Agr. Exp. Sta., *9*, 1897, 119; and *Bacillus urinae* Chester, Man. Determ. Bact., 1901, 263.

Pseudomonas javanica (Eijkmann) Migula syn. *Bacterium javaniensis* Chester, Ann. Rept. Del. Col. Agr. Exp. Sta., *9*, 1897, 111.

Pseudomonas liquida Chester. (*Bacillus liquidus* Frankland and Frankland, Ztschr. f. Hyg., *6*, 1889, 382; Chester, Man. Determ. Bact., 1901, 311; *Achromobacter liquidum* Bergey et al., Manual, 1st ed., 1923, 145.) From water. Originally described merely as motile; Chester recognizes the species as polar flagellate and lists *Bacillus liquefaciens communis* Sternberg and *Bacillus aquatilis communis* Kruse as synonyms.

Pseudomonas longa Migula syn. *Bacterium fluorescens longus* Chester, Ann. Rept. Del. Col. Agr. Exp. Sta., *9*, 1897, 124.

Pseudomonas macroselmis Migula syn. *Bacillus fluorescens putidus* Chester, Ann. Rept. Del. Col. Agr. Exp. Sta., *9*, 1897, 124.

Pseudomonas marinopersica ZoBell and Upham. (Bull. Scripps Inst. of Oceanography, Univ. Calif., *5*, 1944, 275.) From marine bottom deposits.

Pseudomonas melochlora (Winkler and Schrötter) Migula syn. *Bacterium melochlorus* Chester, Ann. Rept. Del. Col. Agr. Exp. Sta., *9*, 1897, 120; see abst. in Cent. f. Bakt., *9*, 1891, 700.

Pseudomonas membranula ZoBell and Upham. (Bull. Scripps Inst. of Oceanography, Univ. Calif., *5*, 1944, 270.) Sessile form found on slide submerged in sea.

Pseudomonas minutissima Migula syn. *Bacterium fluorescens minutissimus* Chester, Ann. Rept. Del. Col. Agr. Exp. Sta., *9*, 1897, 120.

Pseudomonas monadiformis (Kruse) Chester syn. *Bacterium monadiformis* Chester, Ann. Rept. Del. Col. Agr. Exp. Sta., *9*, 1897, 69; *Bacterium coli mobilis* Chester, *ibid.*, 69.

Pseudomonas multistriata (Wright) Chester syn. *Bacterium multistriatus* Chester, Ann. Rept. Del. Col. Agr. Exp. Sta., *9*, 1897, 90.

Pseudomonas nebulosa (Wright) Chester syn. *Bacterium nebulosus* Chester, Ann. Rept. Del. Col. Agr. Exp. Sta., *9*, 1897, 93.

Pseudomonas neritica ZoBell and Upham. (Bull. Scripps Inst. of Oceanography, Univ. Calif., *5*, 1944, 255.) From sea water and marine mud.

Pseudomonas nexibilis (Wright) Chester syn. *Bacterium nexibilis* Chester, Ann. Rept. Del. Col. Agr. Exp. Sta., *9*, 1897, 74.

Pseudomonas obscura ZoBell and Upham. (Bull. Scripps Inst. of Oceanography, Univ. Calif., *5*, 1944, 274.) From marine bottom deposits.

Pseudomonas oceanica ZoBell and Upham. (Bull. Scripps Inst. of Oceanography, Univ. Calif., *5*, 1944, 266.) From marine mud.

Pseudomonas ochracea (Zimmermann) Chester syn. *Bacterium ochraceus* Chester, Ann. Rept. Del. Col. Agr. Exp. Sta., *9*, 1897, 104.

Pseudomonas ovalis Chester syn. *Bacterium fluorescens ovalis* Chester, Ann. Rept. Del. Col. Agr. Exp. Sta., *9*, 1897, 123.

Pseudomonas pallescens Migula syn. *Bacterium viridis pallescens* Chester, Ann. Rept. Del. Col. Agr. Exp. Sta., *9*, 1897, 124.

Pseudomonas perfectomarinus ZoBell and Upham. (Bull. Scripps Inst. of Oceanography, Univ. Calif., *5*, 1944, 277.) From sea water and marine mud.

Pseudomonas periphyta ZoBell and Upham. (Bull. Scripps Inst. of Oceanography, Univ. Calif., *5*, 1944, 276.) Sessile form found in film of marine fouling organisms.

Pseudomonas phosphorescens (Fisher) Bergey et al. syn. *Pasteurella phosphorescens* Trevisan, I generi e le specie delle Batteriacee, 1889, 21; *Bacillus phosphorescens indicus* Eisenberg, Bakt.

Diag., 3 Aufl., 1891, 123; *Vibrio indicus* Lehmann and Neumann, Bakt. Diag., 1 Aufl., *2*, 1896, 341; *Bacterium phosphorescens indicus* Chester, Ann. Rept. Del. Col. Agr. Exp. Sta., *9*, 1897, 120; *Photobacter indicum* Beijerinck, Proc. Sect. Sci., Kon. Akad. v. Wetensch., Amsterdam, *3*, 1900, 352; *Microspira phosphorescens* Chester, Man. Determ. Bact., 1901, 333; *Bacillus indicus* Beijerinck, Folia Mikrobiologica, Delft, I, 1912, 1. Beijerinck (*loc. cit.*, 1900) discusses two variants of this species: *Photobacter indicum* var. *obscurum* and *Photobacter indicum* var. *parvum*. Later, Beijerinck (*loc. cit.*, 1912), in discussing mutants of this species, proposes the species names *Bacillus indicus parvus*, *Bacillus indicus semiobscurus* and *Bacillus indicus obscurus*.

Pseudomonas piscova Hanzawa and Takeda. (Jozogaku Zasshi, Osaka, Japan (Jour. of Zymology), *9*, 1931, 571; quoted from Takeda, Cent. f. Bakt., II Abt., *94*, 1936, 46.) From diseased salmon eggs.

Pseudomonas pleomorpha ZoBell and Upham. (Bull. Scripps Inst. of Oceanography, Univ. Calif., *5*, 1944, 275.) From marine bottom deposits.

Pseudomonas pullulans (Wright) Chester syn. *Bacterium pullulans* Chester, Ann. Rept. Del. Col. Agr. Exp. Sta., *9*, 1897, 105.

Pseudomonas puris Patrick and Werkman. (Proc. Iowa Acad. Sci., *37*, 1930, 57.) From a typhoid-like infection of snakes.

Pseudomonas ribicola Bohn. (Jour. Agr. Res., *73*, 1946, 288.) From the native currant, *Ribes aureum*.

Pseudomonas riboflavinus Foster. (Jour. Bact., *47*, 1944, 30.) Oxidizes riboflavin to lumichrome. From riboflavin-rich soil.

Pseudomonas roseola Humm (*loc. cit.*, 62). From intertidal sand, Atlantic Beach, Nor. Car. Digests agar.

Pseudomonas rugosa (Wright) Chester syn. *Bacterium rugosus* Chester. Ann. Rept. Del. Col. Agr. Exp. Sta., *9*, 1897, 122.

Pseudomonas schuylkilliensis Chester syn. *Bacterium fluorescens schuylkilliensis* Chester, Ann. Rept. Del. Col. Agr. Exp. Sta., *9*, 1897, 119.

Pseudomonas scissa (Frankland and Frankland) Migula syn. *Bacterium scissus* Chester, Ann. Rept. Del. Col. Agr. Exp. Sta., *9*, 1897, 143.

Pseudomonas sessilis ZoBell and Upham. (Bull. Scripps Inst. of Oceanography, Univ. Calif., *5*, 1944, 259.) Sessile form found on solid surfaces submerged in the sea.

Pseudomonas sinuosa (Wright) Chester syn. *Bacterium sinuosus* Chester, Ann. Rept. Del. Col. Agr. Exp. Sta., *9*, 1897, 69.

Pseudomonas smaragdina Migula syn. *Bacterium smaragdino foetidus* Chester, Ann. Rept. Del. Col. Agr. Exp. Sta., *9*, 1897, 119; and *Bacillus smaragdinus* Chester, Man. Determ. Bact., 1901, 263.

Pseudomonas sterotropis ZoBell and Upham. (Bull. Scripps Inst. of Oceanography, Univ. Calif., *5*, 1944, 272.) From a film of marine fouling organisms.

Pseudomonas striata Chester syn. *Bacterium striatus viridis* Chester, Ann. Rept. Del. Col. Agr. Exp. Sta., *9*, 1897, 123.

Pseudomonas syncyanea Migula syn. *Bacterium syncyanus* (sic) Schroeter, Beitr. z. Biol. d. Pflanz., *1*, Heft 2, 1872, 126 and *Bacterium cyanogenum* Zopf, Die Spaltpilze, 2 Aufl., 1884, 50; may be in 1 Aufl.

Pseudomonas synxantha (Ehrenberg) Holland. (*Vibrio synxanthus* Ehrenberg, Verhandl. d. Berl. Akad., 1840, 202; *Vibrio xanthogenes* Fuchs, Magazin f. d. ges. Tierheilk., I, 1841, 193; *Bacterium xanthinum* Schroeter, in Cohn, Beiträge z. Biol. d. Pflanzen, *1*, Heft 2, 1872, 120; *Bacillus synxanthus* Flügge, Die Mikroorganismen, 2 Aufl., 1886, 290; *Flavobacterium synxanthum* Bergey et al., Manual, 1st ed., 1923, 102; Holland, Jour. Bact., *5*, 1920, 220.) Bergey et al.

(Manual, 1st ed., 1923, 102) give *Bacterium xanthogenes* as a synonym. From milk and cream. Polar flagellate (Hammer, personal communication). See Hammer, Res. Bul. 20, Iowa Agr. Exp. Sta., 1915, for a description of this organism.

Pseudomonas tenuis Migula syn. *Bacterium fluorescens tenuis* Chester, Ann. Rept. Del. Col. Agr. Exp. Sta., *9*, 1897, 124.

Pseudomonas turcosa Migula syn. Türkisfarbener *Bacillus*, Tataroff, Inaug. Diss., Dorpat, 1891, 52.

Pseudomonas vadosa ZoBell and Upham. (Bull. Scripps Inst. of Oceanography, Univ. Calif., *5*, 1944, 263.) From sea water and marine bottom deposits.

Pseudomonas vendrelli Tobie. (*Pseudomonas vendralli* (*sic*), mentioned by Farrell and Wolff, Jour. Ind. and Eng. Chem., *33*, 1941, 1186; U. S. Patent 2,227,716, Mar. 1942, issued to Lockwood et al.; *Bacillus vendrelli* Lasseur, Dupaix-Lasseur and Melcion, Travaux Lab. Microbiol. Fac. Pharm. Nancy, Fasc. 13, 1942–43–44, 1944, 293.) Isolated by W. C. Tobie in 1938 from well near Ponce, Puerto Rico owned by Mr. Vendrell (Tobie, Jour. Bact., *52*, 1946, 685). Presumably *Pseudomonas aeruginosa.*

Pseudomonas virescens (Frick) Migula syn. *Bacterium virescens* Chester, Ann. Rept. Del. Col. Agr. Exp. Sta., *9*, 1897, 124.

Pseudomonas viscosa (Frankland and Frankland) Migula syn. *Bacterium viscosus* Chester, Ann. Rept. Del. Col. Agr. Exp. Sta., *9*, 1897, 145; not *Bacterium viscosum* Weldin and Levine, Abst. Bact., *7*, 1923, 16.

Pseudomonas xanthochrus ZoBell and Upham. (Bull. Scripps Inst. of Oceanography, Univ. Calif., *5*, 1944, 279.) From marine bottom deposits.

Ramibacterium alactolyticum Prévot and Taffanel. (Ann. Inst. Past., *68*, 1942, 259.) From an osteophlegmon of the maxillary bone.

Salmonella atherton Ferris, Hertzberg and Atkinson. (Med. Jour. Australia, *32*, 1945, 368.) From 29 cases of gastroenteritis in an army hospital.

Salmonella typhosa (Zopf) White syn. *Bacillus typhicus* Cabral and Da Rocha, I. Trabalhos do Cabinette de Microbiologia; abst. in Ann. de Micrographie, *2*, 1889–1890, 295.

Sarcina pelagia ZoBell and Upham. (Bull. Scripps Inst. of Oceanography, Univ. Calif., *5*, 1944, 279.) From sea water and marine bottom deposits.

Serratia fuchsina Bergey et al. syn. *Proteus fuchsinus* Pribram, Klassifikation der Schizomyceten, Leipzig und Wien, 1933, 73.

Serratia indica (Eisenberg) Bergey et al. syn *Bacillus indicus ruber* Flügge, Die Mikroorganismen, 2 Aufl., 1886, 285; *Bacterium indicum* Crookshank, Manual, 1887, 240.

Spirillum parvum Esmarch. (Cent. f. Bakt., I Abt., Orig., *32*, 1902, 565; also see Zettnow, *ibid.*, *78*, 1916, 1.) From decaying organic matter.

Spirillum sputigenum Flügge. (Lewis, Lancet, Sept. 20, 1884; Flügge, Die Mikroorganismen, 2 Aufl., 1886, 387; *Pacinia lewisi* Trevisan, I generi e le specie delle Batteriacee, 1889, 24.) From sputum.

Staphylococcus activus Prévot and Taffanel. (Ann. Inst. Past., *71*, 1945, 102.) From puerperal septicemia. Anaerobic.

Staphylococcus citreus duodenalis Gessner. (Arch. f. Hyg., *9*, 1889, 136.) From the human duodenum.

Staphylococcus magnus Black. (Trans. Ill. State Dental Soc., *22*, 1886, 188.) From the mouth.

Staphylococcus medius Black. (Trans. Ill. State Dental Soc., *22*, 1886, 190.) From the mouth.

Staphylococcus pyogenes bovis Lucet. (Ann. Inst. Past., *7*, 1893, 327.) From bovine abscesses.

Staphylococcus viscosus Goadby.

(Mycology of the mouth, London, 1903, 172.) From the mouth.

Streptobacterium dextranicum Perquin. (Jour. Microbiol. and Serol., *6*, 1940, 226.) Produces slime from sucrose solutions.

Streptococcus aquatilis Vaughan. (Amer. Jour. Med. Sci., *104*, 1892, 184.) From water.

Streptococcus liquefaciens Frankland and Frankland. (Phil. Trans. Roy. Soc. London, *178*, B, 1888, 264.) From air. After the section covering *Streptococcus liquefaciens* Sternberg *emend.* Orla-Jensen was in page proof, it was discovered that Frankland and Frankland had discovered and named a liquefying streptococcus earlier than Sternberg. The Franklands described this species as producing a yellow pigment.

Streptococcus pyogenes duodenalis Gessner. (Arch. f. Hyg., *9*, 1889, 132.) From the human duodenum.

Streptococcus taette (Olsen-Sopp) Buchanan and Hammer. (*Bacterium lactis longi* Troili-Petersson, Ztschr. f. Hyg., *32*, 1899, 361 and Milchzeitung, *28*, 1899, 438; *Streptobacillus taette* Olsen-Sopp, Cent. f. Bakt., II Abt., *33*, 1912, 9; Buchanan and Hammer, Iowa Sta. Coll. Agr. Exp. Sta., Res. Bull. 22, 1915, 277.) Probably the characteristic organism of Swedish ropy milk. Olsen-Sopp (*loc. cit.*) misquotes Troili-Petersson's name as *Bacillus acidi lactis longus* (see Troili-Petersson, Cent. f. Bakt., II Abt., *38*, 1913, 1).

Thiospira agilissima (Gicklhorn) Bavendamm. (*Spirillum agilissimum* Gicklhorn, Cent. f. Bakt., II Abt., *50*, 1920, 418; Bavendamm, Die farblosen und roten Schwefelbakterien, Pflanzenforschung, Heft 2, 1924, 116.) From the pond in the Annen Castle Park, Graz, Austria. Contains grains of sulfur.

Thiospira elongata Perfiljev. (Ber. d. Sapropel Komm. Petrograd, 1923, 56.) From mud containing H_2S.

Thiospira propera Hama. (Jour. Sci. Hiroshima Univ., Ser. B, Bot., *1*, 1933, 157; abst. in Cent. f. Bakt., II Abt., *91*, 1934, 200.)

Thiospira sulfurica Issatchenko. (Biological observations on the sulfur bacteria (Russian), about 1927, 16 pp.)

Vibrio adaptatus ZoBell and Upham. (Bull. Scripps Inst. of Oceanography, Univ. Calif., *5*, 1944, 258.) From sea water and marine sediments.

Vibrio agarlyticus Cataldi. (Rev. d. Inst. Bact. (D.N.H.), Buenos Aires, *9*, 1940, 375.) From activated sludge. Digests agar.

Vibrio albensis Lehmann and Neumann syn. *Vibrio dunbari* Holland, Jour. Bact., *5*, 1920, 226; probably *Vibrio phosphorescens* Jermoljewa, Cent. f. Bakt., I Abt., Orig., *100*, 1926, 170; not *Vibrio phosphorescens* Holland, *loc. cit.*

Vibrio algosus ZoBell and Upham. (Bull. Scripps Inst. of Oceanography, Univ. Calif., *5*, 1944, 257.) Associated with marine kelp.

Vibrio amphibolus Trevisan. (Babes, Ztschr. f. Hyg., *5*, 1888, 183; Trevisan, I generi e le specie delle Batteriacee, 1889, 23.) Anaerobe.

Vibrio avidus Humm. (Duke Univ. Marine Lab., North Carolina, Bull. 3, 1946, 54.) From intertidal sand, Beaufort, North Carolina. Digests agar.

Vibrio choleroides α and β Bujwid syn. *Bacterium choleroides* Chester, Ann. Rept. Del. Col. Agr. Exp. Sta., *9*, 1897, 131.

Vibrio costicolus Smith and *Vibrio costicolus* var. *liquefaciens* Smith. (Roy. Soc. Queensland, Proc. for 1937, *49*, 1938, 29 and 32.) From tainted ribs of bacon and tank brines in bacon factories. Active growth in 4 to 15 per cent brines.

Vibrio euprima, *Vibrio yasakii*, *Coccobacillus tolega* and *Coccobacillus sepiola* Majima, Sci-i Kwai- Med. Jour. *50*, 1931, 41–67; see Warren, Jour. Bact., *49*, 1945, 548.) Phosphorescent bacteria.

Vibrio fortis Humm (*loc. cit.*, 55). From seaweed (*Gracilaria confervoides*). Digests agar.

Vibrio frequens Humm (*loc. cit.*, 56). From marine algae (*Cladophoropsis*, *Laurencia poitei*, etc.) Digests agar.

Vibrio halonitrificans Smith. (Roy. Soc. Queensland, Proc. for 1937, *49*, 1938, 29.) From tank brines in bacon factories. Active growth in 4 to 10 per cent brines.

Vibrio haloplanktis ZoBell and Upham. (Bull. Scripps Inst. of Oceanography, Univ. Calif., *5*, 1944, 261.) Sessile form found associated with marine phytoplankton.

Vibrio hyphalus ZoBell and Upham. (Bull. Scripps Inst. of Oceanography, Univ. Calif., *5*, 1944, 277.) From marine bottom deposits.

Vibrio marinagilis ZoBell and Upham. (Bull. Scripps Inst. of Oceanography, Univ. Calif., *5*, 1944, 264.) From sea water and marine mud.

Vibrio marinoflavus ZoBell and Upham. (Bull. Scripps Inst. of Oceanography, Univ. Calif., *5*, 1944, 258.) From sea water.

Vibrio marinofulvus ZoBell and Upham. (Bull. Scripps Inst. of Oceanography, Univ. Calif., *5*, 1944, 262.) From sea water.

Vibrio marinopraesens ZoBell and Upham. (Bull. Scripps Inst. of Oceanography, Univ. Calif., *5*, 1944, 256.) From sea water.

Vibrio marinovulgaris ZoBell and Upham. (Bull. Scripps Inst. of Oceanography, Univ. Calif., *5*, 1944, 261.) From sea water.

Vibrio notus Humm (*loc. cit.*, 56). From intertidal sand, Atlantic Beach, North Carolina. Digests agar.

Vibrio perimastrix Alarie. (Alarie, Thesis, MacDonald Coll. McGill Univ., 1945; see Perlin and Michaelis, Sci., *103*, 1946, 673.) Will decompose cellulose only in presence of CO_2.

Vibrio phytoplanktis ZoBell and Upham. (Bull. Scripps Inst. of Oceanography, Univ. Calif., *5*, 1944, 261.) From sea water and marine phytoplankton.

Vibrio pieris Paillot. (Compt. rend. Soc. Biol., Paris, *94*, 1926, 68.) From caterpillars of the cabbage butterfly (*Pieris brassicae*) which had been parasitized by larvae of *Apanteles glomeratus*.

Vibrio ponticus ZoBell and Upham. (Bull. Scripps Inst. of Oceanography, Univ. Calif., *5*, 1944, 259.) From sea water.

Vibrio rumpel Lode. (Cent. f. Bakt., I Abt., Orig., *35*, 1903, 526; see Ballner, Cent. f. Bakt., II Abt., *19*, 1907, 572.) From water. Phosphorescent.

Vibrio stanieri Humm (*loc. cit.*, 57). From seaweed (*Acanthophora spicifera*), Miami, Fla. Digests agar.

Vibrio turbidus Humm (*loc. cit.*, 57). From seaweed (*Gracilaria confervoides*). Digests agar.

Vibrio viridans Miller. (Quoted from Miller, Microorganisms of Human Mouth, Phila., 1890, 85; see Miller, Die Mikroorganismen der Mundhöhle, Leipzig, 1889.) From the mouth.

Xanthomonas translucens var. *phleipratensis* Wallin and Reddy. (Phytopathology, *35*, 1945, 939.) The cause of a bacterial streak disease on timothy grass (*Phleum pratense*).

Xanthomonas vignicola Burkholder. (Phytopath., *34*, 1944, 431.) From cowpea, *Vigna sinensis*.

Yersinia van Loghem (Ann. Past. Inst., *72*, 1946, 975), a genus proposed to include *Pasteurella pestis* and *P. pseudotuberculosis*.

Ein neuer für Thiere path. Mikroorg. aus dem Sputum eines Pneumoniekranken, Bunzel and Federn, Arch. f. Hyg., *19*, 1893; 326; *Bacillus dubius pneumoniae* Kruse, in Flügge, Die Mikroorganismen, 3 Aufl., *2*, 1896, 419; *Bacterium subpneumonicum* Migula, Syst. d. Bakt., *2*, 1900, 376; *Bacterium dubium* Chester, Man. Determ. Bact., 1901, 142. From the sputum of a pneumonia patient.

FAMILY XIII. BACILLACEAE FISCHER.*

(Jahrb. f. wiss. Bot., *27*, 1895, 139.)

Rod-shaped cells, capable of producing spores, either with peritrichous flagella or non-motile; monotrichous flagellation has been reported but is doubtful. Endospores are cylindrical, ellipsoidal or spherical, and are located in the center of the cell, sub-terminally or terminally. Sporangia do not differ from the vegetative cells except when bulged by spores larger than the cell diameter. Such sporangia are spindle-shaped when spores are central, or wedge- or drumstick-shaped when spores are terminal. Usually Gram-positive. Pigment formation is rare. Aerobic, microaerophilic or anaerobic. Gelatin is frequently liquefied. Sugars are generally fermented, sometimes with the formation of visible gas. Some species are thermophilic, i.e., will grow readily at 55°C. Mostly saprophytes, commonly found in soil. A few are animal, especially insect, parasites or pathogens.

Key to the genera of family **Bacillaceae.**

I. Aerobic; catalase positive.
Genus I. *Bacillus*, p. 705.

II. Anaerobic or microaerophilic; catalase not known to be produced.
Genus II. *Clostridium*, p. 763.

INTRODUCTION TO THE GENUS BACILLUS.

In the fifth edition of the MANUAL, the late F. D. Chester stated: "It is difficult to offer a rational system of classification for the described forms of the genus *Bacillus* because of the incompleteness of the data". He prepared a splendid review of the literature but naturally could not supply the data that were missing. He stated further that "The majority of the so-called species in the genus have been imperfectly presented, . . . the net result being that there are comparatively few clearly and definitely described species among the many herein recorded. The development of a better knowledge will be a work of the future". He then discussed the type of work that should be done. A reading of his statement is recommended to anyone contemplating naming a new species.

During the past few years, the writer with the assistance of Francis E. Clark and Ruth E. Gordon has made a study of the genus *Bacillus* along the lines indicated by Chester. Representative cultures have been obtained from various laboratories, institutions, and private collections. Special mention should be made of the private collection of Prof. J. R. Porter, now at the Iowa State University. It contained about 200 named species and was invaluable for the work. As a result of this study, it appears that many species have been differentiated by such simple characters as mucoid, folded, adherent or rhizoid growth, pigment production, the fermentation of a specific carbohydrate, etc. Others have been grouped because of some special physiological activity such as the decomposition of calcium n-butyrate, xylan, cellulose, etc. Chester rightly considered that these physiological groups had no taxonomic value.

Species have been characterized upon a broad basis in the present arrangement on the assumption that one species should not dissociate into another species. Since certain characters are more stable than others, these have been used to establish a

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* Revised by Mr. Nathan R. Smith, U. S. Bureau of Plant Industry Station, Beltsville, Maryland (*Bacillus*), August, 1943, and Prof. R. S. Spray, School of Medicine, West Virginia University, Morgantown, West Virginia (*Clostridium*), May, 1942.

species pattern. This has reduced the number of species of the mesophilic members of the genus from many poorly defined organisms to a few well characterized and delimited species. Intermediates occur between related species and have been treated as such. The report on which this arrangement is based has recently been published by Smith, Gordon and Clark (U. S. Dept. Agr. Misc. Pub. No. 559, 1946, 112 pp.).

Some workers may think that the cut in the number of species has been too drastic and that certain organisms listed as varieties, morphotypes, or biotypes should be retained as species. This would not be consistent with the newer knowledge of bacteriology that has been developed during the past two decades. No doubt other species occur in nature that are not included herein. But before jumping to the conclusion that a culture *is* a new species, closely related organisms as well as the isolate should be studied along the lines given by Chester in the fifth edition of the MANUAL.

The production of indole and the formation of H_2S have been omitted from the descriptions because these characters have no taxonomic value. Certain other properties, such as colony form, character of the growth on slants, in litmus milk, etc., have a very limited value. They are included for the sake of completeness.

Genus I. Bacillus *Cohn.**

(Beiträge z. Biol. d. Pflanzen, *1*, Heft 2, 1872, 146 and 175.) From Latin *bacillum*, a small stick.

Synonyms: ? *Bactrella* Morren, Bull. d. Sci. natur et de Geol., No. 27, 1830, 203; ? *Metallacter* Perty, Zur Kenntniss kleinster Lebensformen, 1852, 180; ? *Bacteridium* Davaine, Dict. Encyclop. d. Sci. Méd., Ser. I, *8*, 1868, 21; *Pollendera* Trevisan, 1884 (see DeToni and Trevisan, in Saccardo, Sylloge Fungorum, *8*, 1889, 943); *Zopfiella* Trevisan, Atti della Accademia Fisio-Medico-Statistica in Milano, Ser. 4, *3*, 1885, 93; *Cornilia* Trevisan, I generi e le specie delle Batteriacee, 1889, 21; *Urobacillus* Miquel, Ann Microg., *1*, 1889, 517; *Bacterium* Migula, Arb. bakt. Inst. Karlsruhe, *1*, 1894, 237 (not *Bacterium* Ehrenberg, Symbolae Physicae seu Icones et Descriptiones Animalium, etc., Berlin, 1828, 8); *Bactrinum*, *Bactridium*, *Bactrillum*, *Clostrillium*, *Clostrinium* and *Paracloster* Fischer, Jahresb. f. wissensch. Bot., *27*, 1895, 139; *Endobacterium* Lehmann and Neumann, Bakt. Diag., 1 Aufl., *2*, 1896, 103; *Astasia* Meyer, Flora, *84*, 1897, 185; *Saccharobacter* Beijerinck, Cent. f. Bakt., II Abt., *6*, 1900, 200; *Fenobacter* Beijerinck, *ibid.*; *Aplanobacter* E. F. Smith, Bact. in Relation to Plant Dis., *1*, 1905, 171; *Semiclostridium* Maassen, Arb. a. d. k. Gesundheitsamte, Biol. Abt., *5*, 1905, 5; *Myxobacillus* Gonnermann, Ztschr. f. Zuckerind. u. Landwirtsch., *36*, 1907, 877; *Plennobacterium* Gonnermann, *ibid.*; *Serratia* Vuillemin, Ann. Mycolog., *11*, 1913, 521 (not *Serratia* Bizio, Polenta porporina, Biblio. Ital., *30*, 1823, 288); *Schaudinnum*, *Theciobactrum*, *Zygostasis*, *Eisenbergia*, *Migulanum* and *Rhagadascia* Enderlein, Sitzber. Gesell. Naturf. Freunde, Berlin, 1917,309; *Cellulobacillus* Simola, Ann. Ac. Sc. Fenn., Ser. A, *34*, No. 1 and 6, 1931 (abst. in Cent. f. Bakt., II Abt., *86*, 1932, 89); not *Cellulobacillus* Orla-Jensen, Cent. f. Bakt., II Abt., *22*, 1909, 343; *Zymobacillus* Kluyver and Van Niel, Cent. f. Bakt., II Abt., *94*, 1936, 369.

Rod-shaped bacteria, sometimes in chains. Sporangia usually not different from the vegetative cells. Catalase present. Aerobic, sometimes showing rough colonies and

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* Revised by Mr. Nathan R. Smith, U. S. Bur. Plant Industry Station, Beltsville, Maryland, August, 1943.

forming a pellicle on broth. Usually oxidize carbohydrates or proteins more or less completely, often producing slight acidity, without pronounced accumulation of characteristic products. Soil is the most common habitat.

The internationally accepted (Jour. Bact., *33*, 1937, 445) type species is *Bacillus subtilis* Cohn *emend.* Prazmowski.

Key to the species of genus **Bacillus.**

I. Mesophilic (good growth at 30°C), aerobic (sometimes also grow at low concentrations of oxygen).
  A. Spores ellipsoidal to cylindrical, central to terminal, walls thin. Sporangia not distinctly bulged. Gram-positive.
    1. Diameter of rods less than 0.9 micron. Cells from glucose or glycerol nutrient agar stain uniformly.
      a. Growth at pH 6.0. Acetylmethylcarbinol produced.
        b. Gelatin hydrolyzed (Frazier method). Acid from xylose or arabinose with ammoniacal nitrogen.
          c. Starch hydrolyzed. Nitrites produced from nitrates.
            1. *Bacillus subtilis.*
            d. Black pigment on carbohydrate media only.
              1a. *Bacillus subtilis* var. *aterrimus.*
            dd. Black pigment on tyrosin media only.
              1b. *Bacillus subtilis* var. *niger.*
          cc. Starch not hydrolyzed. Nitrites not formed from nitrates.
            2. *Bacillus pumilus.*
        bb. Gelatin not hydrolyzed. No acid from xylose or arabinose.
          3. *Bacillus coagulans.*
      aa. No growth at pH 6.0. Acetylmethylcarbinol not formed.
        b. Casein digested. Urease not formed.
          4. *Bacillus firmus.*
        bb. Casein not digested. Urease produced.
          5. *Bacillus lentus.*
    2. Diameter of rods 0.9 micron or more. Cells from glucose or glycerol nutrient agar appear vacuolated if lightly stained.
      a. Acid from xylose or arabinose with ammoniacal nitrogen. Acetylmethylcarbinol not produced.
        6. *Bacillus megatherium.*
      aa. No acid from xylose or arabinose. Acetylmethylcarbinol produced.
        b. Saprophytic, sometimes pathogenic but not causing anthrax; usually motile.
          c. Growth on agar not rhizoid.
            7. *Bacillus cereus.*
          cc. Rhizoid growth on agar; usually non-motile.
            7a. *Bacillus cereus* var. *mycoides.*
        bb. Pathogenic. Causative agent of anthrax; non-motile.
          8. *Bacillus anthracis.*
  B. Spores ellipsoidal, central to terminal, walls thick, remnants of sporangium often adhering. Sporangia distinctly bulged, spindle and racket forms. Gram-variable.
    1. Acid and gas from carbohydrates.
      a. Acetylmethylcarbinol produced. Crystalline dextrins not formed from starch.

9. *Bacillus polymyxa.*

aa. Acetylmethylcarbinol not produced. Crystalline dextrins formed from starch.

10. *Bacillus macerans.*

2. No visible gas from carbohydrates.

a. Saprophytic. Growth on ordinary media.

b. pH of glucose, proteose-peptone broth cultures less than 8.0. Citrates not used as source of carbon.

c. Starch hydrolyzed. Acid from sucrose with ammoniacal nitrogen.

d. Acid from xylose or arabinose with ammoniacal nitrogen. Acetylmethylcarbinol not formed.

11. *Bacillus circulans.*

dd. No acid from xylose or arabinose. Acetylmethylcarbinol produced.

12. *Bacillus alvei.*

cc. Starch not hydrolyzed. No acid from sucrose.

13. *Bacillus laterosporus.*

bb. pH of glucose, proteose-peptone broth cultures 8.0 or higher. Citrates used as source of carbon.

14. *Bacillus brevis.*

aa. Parasitic. No growth on ordinary media.

b. Cause of American foulbrood of honey bees.

15. *Bacillus larvae.*

bb. Cause of the milky disease of Japanese beetles (*Popillia japonica* Newm.).

Type A. 16. *Bacillus popilliae.*

Type B. 17. *Bacillus lentimorbus.*

C. Spores spherical, central to terminal. Sporangia definitely bulged, drumsticks and spindles. Carbohydrates not attacked. Gram-variable.

1. Growth on nutrient agar without urea or free ammonia.

a. Urease not formed.

18. *Bacillus sphaericus.*

aa. Urease produced.

18a. *Bacillus sphaericus* var. *fusiformis.*

2. No growth on nutrient agar without urea or free ammonia. Urease formed.

19. *Bacillus pasteurii.*

II. Thermophilic, optimum temperatures 55°C or above; slight if any growth at 37°C. Aerobic.*

A. Spores ellipsoidal to cylindrical, central to terminal; sporangia not distinctly bulged.

1. Diameter of rods less than 0.8 micron.

a. Gas from carbohydrates.

20. *Bacillus thermoamylolyticus.*

aa. No gas from carbohydrates.

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* The data on the species of this group are so meager that it is not possible to offer a rational system of classification. Many of the characters used for separating the various species are probably as variable in this group as they have been found to be in the mesophilic group. Lacking a knowledge of the limits of variability and lacking other pertinent data, the present arrangement is regarded as temporary only.

b. Growth below 50°C.
c. Nitrites from nitrates, often with liberation of nitrogen gas.
21. *Bacillus kaustophilus.*
21a. *Bacillus pepo.*
cc. No nitrites from nitrates.
22. *Bacillus thermoindifferens.*
bb. No growth below 50°C.
23. *Bacillus thermodiastaticus.*
2. Diameter of rods greater than 0.8 micron.
a. Growth on nutrient agar.
b. Remnants of sporangium adherent.
24. *Bacillus cylindricus.*
bb. Remnants of sporangium not adherent.
25. *Bacillus robustus.*
25a. *Bacillus losanitchii.*
aa. No growth on nutrient agar.
26. *Bacillus calidolactis.*
B. Spores ellipsoidal to cylindrical, central to terminal; sporangia distinctly bulged.
1. Diameter of rods less than 0.9 micron.
a. Starch hydrolyzed.
b. Nitrites from nitrates, sometimes with liberation of nitrogen gas.
27. *Bacillus michaelisii.*
27a. *Bacillus lobatus.*
27b. *Bacillus thermononliquefaciens.*
bb. No nitrites from nitrates.
c. Action on cellulose not recorded.
28. *Bacillus thermotranslucens.*
28a. *Bacillus stearothermophilus.*
28b. *Bacillus aerothermophilus.*
cc. Cellulose hydrolyzed.
29. *Bacillus thermocellulolyticus.*
aa. Starch not hydrolyzed.
b. Nitrites from nitrates, sometimes with gaseous nitrogen.
c. Milk unchanged.
30. *Bacillus thermoalimentophilus.*
cc. Milk acid, coagulated.
31. *Bacillus thermoliquefaciens.*
2. Diameter of rods greater than 0.9 micron.
a. Starch hydrolyzed.
b. No nitrites from nitrates.
32. *Bacillus tostus.*
C. Spores spherical, central to terminal; sporangium not distinctly bulged.
33. *Bacillus viridulus.*

1. **Bacillus subtilis** Cohn *emend.* Prazmowski. (Cohn, Beitr. z. Biol. d. Pflanzen, *1*, Heft 2, 1872, 174; Heft 3, 1875, 188; *2*, Heft 2, 1876, 249; Prazmowski, Untersuchungen über die Entwicklungsgeschichte und Fermentwirkung einigen Bakterien-Arten. Inaug. Diss., Leipzig, 1880.) From Latin *subtilis*, thin, slender.

The identity of this species has been

the subject of some controversy owing to the indefiniteness of the original descriptions, to the distribution of cultures under the name *Bacillus subtilis* that were incorrectly identified, to variations in the forms of growth that may be observed, and to confusion with *Bacillus cereus*. In cases where *Bacillus subtilis* is said to be "anthrax-like," or "similar to the anthrax bacillus," it should be remembered that these terms apply to *Bacillus cereus* and not to *Bacillus subtilis*. Conn (Jour. Inf. Dis., *46*, 1930, 341) concluded that the so-called Marburg strain fitted the earliest recognizable description of this species which is that given by Prazmowski (*loc. cit.*), and his view was accepted after a study of cultures by the International Committee on Bacteriological Nomenclature (Jour. Bact., *33*, 1937, 445).

During the past two decades much progress has been made in the study of variations in the stages of growth of bacteria, the rough, smooth, mucoid, etc., and in the variability in physiology as well. From the recent work of Smith, Gordon, and Clark (*loc. cit.*) it appears that many species have been characterized on such simple grounds as growth folded, mucoid, adherent, colored, rhizoid, etc., all of which are subject to variation, either induced or spontaneous. The present arrangement of this species is the result of their work combined with data supplied by the work of Conn and others.

Species probably identical with or variants of *Bacillus subtilis:*

Bacillus geniculatus de Bary, Beitrag zur Kenntnis der niederen Organismen im Mageninhalt, Inaug. Diss., Strassburg, Leipzig, 1885; *Bacillus mesentericus fuscus* Flügge, Die Mikroorganismen, 2 Aufl., 1886, 321 (*Bacillus mesentericus* Trevisan, I generi e le specie delle Batteriacee, 1889, 19; not *Bacillus mesentericus* as interpreted by Chester, Del. Agr. Exp. Station 15th Ann. Report, 1903, 86; not *Bacillus mesentericus* as given by Lawrence and Ford, Jour. Bact., *1*, 1916, 295);* *Bacillus mesentericus vulgatus* Flügge, Die Mikroorganismen, 2 Aufl., 1886, 322 (*Bacillus vulgatus* Trevisan, I generi e le specie delle Batteriacee, 1889, 19); *Bacillus liodermos* Flügge, Die Mikroorganismen, 2 Aufl., 1886, 323 (Bacillus No. X, Flügge, Ztschr. f. Hyg., *17*, 1894, 296; *Bacillus lactis* No. X, Kruse, in Flügge, Die Mikroorganismen, 3 Aufl., *2*, 1896, 209; *Bacillus intermedius* Migula, Syst. d. Bakt., *2*, 1900, 579; *Bacillus cremoris* Chester, Man. Determ. Bact., 1901, 274); *Bacillus laevis* Frankland and Frankland, Philos. Trans. Roy. Soc. London, *178*, B, 1887, 278 (not *Bacillus laevis* Distaso, Cent. f. Bakt., I Abt., Orig., *62*, 1912, 444); *Tyrothrix tenuis* Duclaux, Ann. Inst. Nat. Agron., *4*, 1882, 23 (*Bacillus tenuis* Trevisan, I generi e le specie delle Batteriacee, 1889, 16); Kartoffelbacillus, Globig, Ztschr. f. Hyg., *3*, 1888, 294 (*Bacillus roseus* Trevisan, *loc. cit.*, 19; *Bacillus mesentericus ruber* Kruse, in Flügge, Die

*T. Gibson, University of Edinburgh (personal communication), has found that the European and supposedly the original strains of *Bacillus mesentericus* hydrolyze starch and reduce nitrates to nitrites, whereas the American strains are negative in both of these characters. Furthermore, the latter are usually smooth and when the rough stage exists, it does not resemble a mesentery from which the organism derived its name. This term, however, can still be applied to the European strains. Since the American strains are identical with *Bacillus pumilus* (Chester, Del. Agr. Exp. Station, 15th Ann. Report, 1903, 87; Lawrence and Ford, Jour. Bact., *1*, 1916, 300), it has been recommended (Smith, Gordon, and Clark, *loc. cit.*) that they be designated as *Bacillus pumilus* to avoid ambiguity. Since the European *Bacillus mesentericus* is only a stage of growth of *Bacillus subtilis*, the former name should be dropped.

Mikroorganismen, *2*, 1896, 199; *Bacillus globigii* Migula, Syst. der Bakt., *2*, 1900, 554; *Bacillus vitalis* Chester, Man. Determ. Bact., 1901, 286); *Bacillus leptosporus* Klein, Cent. f. Bakt., *6*, 1889, 316; *Bacillus* No. 6, Pansini, Arch. f. path. Anat. u. Physiol., *122*, 1890, 422 (*Bacillus coccoideus* Migula, Syst. der Bakt., *2*, 1900, 558); *Bacillus radians* Migula, Syst. d. Bakt., *2*, 1900, 580 (Bacillus No. IX, Flügge, Ztschr. f. Hyg., *17*, 1894, 296; *Bacillus lactis* No. IX, Kruse, in Flügge, Die Mikroorganismen, 3 Aufl., *2*, 1896, 209; *Bacillus stellatus* Chester, Man. Determ. Bact., 1901, 274; not *Bacillus stellatus* Vincent, Ann. Inst. Past., *21*, 1907, 69); *Bacillus mesentericus panis viscosi II* Vogel, Ztschr. f. Hyg., *26*, 1897, 404 (*Bacillus panis* Migula,** Syst. der Bakt., *2*, 1900, 576); *Bacillus armoraciae* Burchard, Arb. a. d. bakt. Inst. d. techn. Hochschule zu Karlsruhe, *2*, 1898, 46; *Bacillus idosus* Burchard, *ibid.*, 47; *Bacillus subtilis α* Gottheil, Cent. f. Bakt., II Abt., *7*, 1901, 635; *Bacillus natto* Sawamura, Bull. Coll. Agr., Tokyo, *7*, 1906, 108; *Bacillus mesentericus* var. *flavus* Laubach, Jour. Bact., *1*, 1916, 497 (*Bacillus flavus* Bergey et al., Manual, 1st ed., 1923, 286; not *Bacillus flavus* Fuhrmann, Cent. f. Bakt., II Abt., *19*, 1907, 117); *Bacillus truffauti* Truffaut and Bezssonoff, Compt. rend. Acad. Sci., Paris, *175*, 1922, 544; *Bacillus mesentericus hydrolyticus* Hermann and Neuschul, Biochem. Ztschr., *281*, 1935, 219.

The name *Vibrio subtilis* Ehrenberg (Infusionsthierchen als vollkommene Organismen, Leipzig, 1838) seems to have given rise to the species name.

Spores: 0.6 to 0.9 by 1.0 to 1.5 microns, ellipsoidal to cylindrical, central or paracentral. Germination prevailingly equatorial.

Sporangia: Ovoid to cylindrical, only slightly bulged if at all.

Rods: 0.7 to 0.8 by 2.0 to 3.0 microns, single or in short chains, rounded ends, stain uniformly. Motile. Gram-positive. The following variations have been observed: Smaller or larger rods, filaments, encapsulated cells (the slimy bread organisms), few shadow forms, non-motile and Gram-variable. Rods on glucose nutrient agar store small amount of fat.

Gelatin stab: Liquefaction.

Agar colonies: Usually rough, finely wrinkled, opaque, dull, adherent, slightly spreading, brownish tinge. Variations may be smooth, soft, thin, translucent, non-adherent, dendroid, coarsely wrinkled, creamy-white to yellowish to orange.

Agar slants: Growth abundant, flat, spreading, usually has a dull mat surface, finely wrinkled, adherent, becoming slightly brownish. Variations may be coarsely wrinkled or folded, non-adherent, smooth, thin, translucent, dendroid, creamy-white to yellow to orange. Some strains show a greenish fluorescence when grown at 45°C on nutrient agar.

Broth: Turbid becoming clear with formation of a tough, wrinkled pellicle.

Milk: Slowly peptonized, becoming alkaline.

** There has been confusion about the identity of the so-called slimy bread bacteria. Lehmann and Neumann (Bakt. Diag., 7 Aufl., *2*, 1927, 616) stated that they were interrelated and also more or less closely related to *Bacillus mesentericus* and to *Bacillus vulgatus*. Laubach (Jour. Bact., *1*, 1916, 501) isolated a strain of *Bacillus panis* that lost its capsules on artificial media, although it still remained slimy. From this and the work of Smith, Gordon and Clark (*loc. cit.*) it is apparent that the slimy bread organisms are mucoid variants of *Bacillus subtilis*, which may or may not be encapsulated, and motile or non-motile (see also *Bacillus subtilis* var. *viscosus* Chester, Del. Agr. Exp. Station, 15th Ann. Report, 1903, 84).

Milk agar plate: Casein hydrolyzed.

Potato: Growth luxuriant, warty or wrinkled to coarsely folded, whitish to pink or yellow, becoming brownish with age.

Nitrites formed from nitrates.

Starch is hydrolyzed.

Acid with ammoniacal nitrogen from xylose, arabinose, glucose, fructose, galactose, mannose, maltose, sucrose, salicin, glycerol, and mannitol. Usually acid from dextrin. Variable reactions on rhamnose, raffinose, and inulin. Usually no action on lactose.

Acetylmethycarbinol produced.

Citrates utilized.

Optimum temperature 30° to 37°C. Will usually grow from 50° to 56°C.

Aerobic, facultative.

Source: Original cultures isolated by Cohn from an infusion of lentils (1872), from a boiled infusion of cheese and white beets (1875), and from boiled hay infusions (1876). Hence, frequently called the hay bacillus. The folded, non-adherent stage of growth (*Bacillus vulgatus* and the European strain of *Bacillus mesentericus*) is often called the potato bacillus. Manner of germination of spores established by Prazmowski (*loc. cit.*).

Habitat: Widely distributed in soil and in decomposing organic matter.

Note: *Bacillus vulgatus* has long been separated from *Bacillus subtilis* by the folded character and the non-adherence of its growth. Recently Lamanna (Jour. Bact., *44*, 1942, 611) has attempted to separate this species from *Bacillus subtilis* by the splitting of the spore sheath along the transverse axis upon germination. Since the two species are otherwise morphologically and physiologically alike and since these characters are subject to much variation, there seems to be no valid reason for this separation. One can, if he desires, indicate the different stages of growth; for instance, *Bacillus subtilis* morphotype *vulgatus* (or *mesentericus*) for the folded growth, *Bacillus subtilus* morphotype *panis* for the slimy growth, and *Bacillus subtilis* morphotype *globigii* for those that produce a red or orange pigment. These terms would apply to the present condition of the culture and would have to be changed if the character of the growth changed.

1a. *Bacillus subtilis* var. *aterrimus* *comb. nov.* (Potato bacillus, Biel, Cent. f. Bakt., II Abt., *2*, 1896, 137; *Bacillus aterrimus* Lehmann and Neumann, Bakt. Diag., 1 Aufl., *2*, 1896, 303; *Bacillus mesentericus niger* Lunt, Cent. f. Bakt., II Abt., *2*, 1896, 572; *Bacillus niger* Chester, Man. Determ. Bact., 1901, 306.) From Latin *aterrimus*, very black.

Synonyms: *Bacillus nigrificans* Fabian and Nienhuis, Mich. Agric. Exp. Station, Tech. Bull. 140, 1934, 24; *Bacillus tyrosinogenes* Rusconi, as referred to by Carbone et al., Instit. Sierot. Milan., *2*, 1921–1922, 29; not *Bacillus tyrosinogenes* Hall and Finnerud, Proc. Soc. Expl. Biol. and Med., *19*, 1921, 48 and Hall, Abstr. Bact., *6*, 1922, 6.

In the early accounts the production of a blue-black to black pigment on potato was stressed. It was also said to resemble *Bacillus subtilis* and *Bacillus vulgatus* on gelatin plates. Recent work (Clark and Smith, Jour. Bact., *37*, 1939, 280) has shown that pigmentation occurs only in the presence of a carbohydrate. In addition (Gordon and Smith, Jour Bact., *43*, 1942, 55), it was established that the ability to form the pigment could be lost through serial transfers and colony selection and that the resultant dissociants could not be differentiated from *Bacillus subtilis*.

Source: Isolated from rye bread in moist chamber used for growing some aspergilli (Biel).

Habitat: Widely distributed in soil.

1b. *Bacillus subtilis* var. *niger* *comb. nov.* (*Bacillus lactis niger* Gorini, Gior. d. Reale Soc. Ital. Ig., *16*, 1894, 9; *Bacil-*

lus niger Migula, Syst. der Bakt., *2*, 1900, 636.) From Latin *niger*, black.

The black pigment characterizing this organism is formed only in media containing tyrosine (Clark and Smith, Jour. Bact., *37*, 1939, 279). The ability to form the pigment may be lost through serial transfer and colony selection. It then cannot be separated from *Bacillus subtilis* (Gordon and Smith, *loc. cit.*).

Source: First isolated from milk.

Habitat: Widely distributed in soil.

2. **Bacillus pumilus** Gottheil. (Cent. f. Bakt., II Abt., 7, 1901, 681.) From Latin *pumilus*, dwarfish, little.

Synonyms: *Bacillus mesentericus* as interpreted by Chester, Del. Agric. Exp. Station, 15th Ann. Report, 1903, 87; *Bacillus mesentericus* as given by Lawrence and Ford, Jour. Bact., *1*, 1916, 295 and 300; *Bacillus mesentericus* var. *flavus* Laubach, Jour. Bact., *1*, 1916, 497; perhaps also *Bacillus parvus* Neide, Cent. f. Bakt., II Abt., *12*, 1904, 344; *Bacillus leptodermis* Burchard, Arb. a. d. bakt. Inst. d. techn. Hochschule zu Karlsruhe, *2*, 1898, 33.

Spores: Ellipsoidal to cylindrical, thin walled, naked, central or paracentral, usually about 0.5 by 1.0 micron although some may approach the size of those of *Bacillus subtilis*.

Sporangia: Ellipsoidal to cylindrical, not bulged.

Rods: 0.6 to 0.7 by 2.0 to 3.0 microns, usually occurring singly or in pairs. Chains, filaments and shadow forms may be found in some strains. Cells grown on glucose nutrient agar have few small fat globules. Motile with peritrichous flagella. Gram-positive.

Gelatin stab: Slow liquefaction.

Agar colonies: Thin, flat, spreading, dendroid, smooth, translucent. The rough stage also occurs.

Agar slants: Growth moderate, smooth, soft, thin, glistening, non-adherent, spreading, usually whitish although it may be yellowish. The rough stage is tough and finely wrinkled, sometimes resembling certain strains of *Bacillus subtilis*.

Broth: Uniform turbidity, with or without a ring or half-formed pellicle. The rough stage forms a pellicle.

Milk: Peptonized, sometimes coagulated.

Milk agar plate: Casein hydrolyzed.

Potato: Growth is smooth, thin, spreading, moist to slimy, yellowish, turning somewhat brown. The rough stage is dry and finely wrinkled.

Nitrites not produced from nitrates.

Starch not hydrolyzed.

Acid with ammoniacal nitrogen from arabinose, xylose, glucose, fructose, galactose, mannose, sucrose, salicin, glycerol and mannitol; usually also from maltose and raffinose. Reaction variable with dextrin. Usually no acid from rhamnose, lactose, and inulin.

Acetylmethylcarbinol produced.

Citrates utilized as sole source of carbon.

Optimum temperature about 30°C. Maximum temperature allowing growth usually about 50°C.

Aerobic.

Source: Isolated from plants, cheese, dust, and as a contaminant of media.

Habitat: Widely distributed in nature.

3. **Bacillus coagulans** Hammer. (Iowa Agric. Exp. Station, Research Bull. 19, 1915, 129; Sarles and Hammer, Jour. Bact., *23*, 1932, 301.) From Latin *coagulans*, curdling, coagulating.

Synonyms: *Bacillus thermoacidurans* Berry, Jour. Bact., *25*, 1933, 72; *Bacillus dextrolacticus* Andersen and Werkman, Iowa State Coll. Jour. of Sci., *14*, 1940, 187.

Spores: Ellipsoidal to cylindrical, terminal or subterminal, thin walled, 0.6 to 0.9 by 1.0 to 1.5 microns. Sporulation better on acid proteose peptone agar (Stern, Hegarty, and Williams, Food Research, 7, 1942, 186).

Sporangia: Only slightly swollen, if at all.

Rods: 0.5 to 0.9 by 2.5 to 3 microns, singly or in short chains, resemble *Bacillus subtilis*. Cells from glucose agar contain few small fat globules. Motile. Gram-positive.

Gelatin: No growth at 20°C. No change in gelatin by Frazier method at 45°C.

Agar colonies: Small, entire, raised, not characteristic.

Agar slants: Growth scant to moderate, thin, flat. On acid proteose peptone agar growth is more abundant and microscopically the cells appear healthier.

Broth: Moderate uniform turbidity, followed by clearing. Glucose broth attains a pH of 4.0 to 4.4.

Milk: Coagulated.

Milk agar plate: Weak hydrolysis of casein.

Potato: Growth scant to moderate, thin, spreading, white to cream-colored. May have a sour odor.

Nitrites usually not formed from nitrates.

Starch is hydrolyzed.

Acid from glucose, galactose, fructose, lactose, maltose, sucrose, dextrin, and glycerol. Usually no acid from arabinose and sorbitol. No acid from xylose and mannitol. Organic nitrogen preferable to inorganic.

Acetylmethylcarbinol produced.

Citrates not used as sole source of carbon.

Optimum temperature about 45°C (Hammer, 55°C). Maximum temperature allowing growth 54°C to 60°C. Slow growth, if any, at 25°C.

Aerobic, facultative.

Source: Isolated from evaporated milk (Hammer) and tomato juice (Berry).

Habitat: Canned goods; probably widely distributed in nature.

4. **Bacillus firmus** Werner. (Cent. f. Bakt., II Abt., *87*, 1932, 470.) From Latin *firmus*, firm, strong.

Spores: Usually ellipsoidal, central to subterminal, 0.6 to 0.7 by 1.0 to 1.2 microns on Ca-n-butyrate agar (Werner); 0.7 to 0.9 by 1.0 to 1.4 microns on nutrient agar. Sporulation better on plain peptone agar than on nutrient agar.

Sporangia: Ellipsoidal to cylindrical, sometimes slightly bulged.

Rods: 0.6 to 0.9 by 1.5 to 4.0 microns, single or in short chains, few filaments. On glucose nutrient agar there are swollen, shadow, and other abnormal forms, few small fat globules. Motile with peritrichous flagella. Gram-positive.

Gelatin stab: Slow liquefaction. Gelatin plate shows wide zone of hydrolysis.

Agar colonies: Small, smooth, dense, entire, white to pink.

Agar slants: Growth moderate, smooth, opaque, not spreading, whitish. Pink variations may occur. Growth inhibited when glucose is added, because of the production of acid. No growth at pH 6.0 or below.

Broth: Scant uniform turbidity or a flocculent growth.

Milk agar plate: Weak to strong casein hydrolysis.

Potato: No growth.

Nitrites produced from nitrates.

Starch is hydrolyzed.

Acid from glucose. No acid from arabinose and xylose. Ammonium salts not used as sole source of nitrogen.

Acetylmethylcarbinol not produced.

Citrates usually not utilized.

Urease not produced.

Salt tolerance: Will grow in nutrient broth containing 4 to 7 per cent NaCl.

Optimum temperature about 28°C. Maximum temperature allowing growth 37°C to 45°C.

Source: Seven strains isolated from soils in Central Europe and Egypt.

Habitat: Widely distributed in soil.

5. **Bacillus lentus** Gibson. (Cent. f. Bakt., II Abt., *92*, 1935, 368.) From Latin *lentus*, slow.

Spores: Ellipsoidal, central to subterminal, 0.7 to 0.8 by 1.0 to 1.3 microns.

Sporangia: Ellipsoidal to cylindrical, may be slightly swollen.

Rods: 0.6 to 0.7 by 2.0 to 3.0 microns, occurring singly or in pairs. Motile with peritrichous flagella. Gram-positive.

Gelatin stab: No liquefaction. No change in gelatin by Frazier method.

Agar colonies: Small, smooth, entire, glistening, white, opaque.

Agar slants: Growth only moderate, slow, thin, gray to white, opaque, not spreading. No growth at pH 6.0 or below. Growth inhibited by glucose because of the change to acid reaction.

Broth: Faint uniform turbidity, granular sediment.

Milk: Unchanged.

Milk agar plate: Casein not hydrolyzed.

Potato: No growth.

Nitrites not produced from nitrates.

Starch is hydrolyzed.

Acid from arabinose, xylose, glucose, sucrose, and lactose. Inorganic nitrogen not utilized.

Acetylmethylcarbinol not formed.

Citrates not used as sole source of carbon.

Urease produced. Urea decomposed at room temperature, feebly at 37°C.

Salt tolerance: Will grow in nutrient broth containing 4 per cent NaCl.

Optimum temperature about 25°C. Maximum temperature allowing growth 37°C.

Growth on most media is increased by the addition of urea.

Aerobic.

Source: Nine strains isolated from soils.

Habitat: Common in soils.

6. **Bacillus megatherium** De Bary. (*Bacillus megaterium* (sic) De Bary, Vergleichende Morph. und Biol. der Pilze, 1884, 499.) Generally assumed that the original spelling was a typographical error and that the later spelling *megatherium* comes from Greek roots meaning big animal (Breed, Science, *70*, 1929, 480). Rippel (Arch. Mikrobiol., *11*, 1940, 470) holds that the original spelling meaning big rod is the correct form.

Synonyms as given by Smith, Gordon, and Clark (*loc. cit.*): *Bacillus capri* Stapp, Cent. f. Bakt., II Abt., *51*, 1920, 19; *Bacillus carotarum* Koch, Bot. Zeit., *18*, 1888, 277 (*Bacterium carotarum* Migula, Syst. d. Bakt., *2*, 1900, 293); *Bacillus cobayae* Stapp, Cent. f. Bakt., II Abt., *51*, 1920, 10; *Bacillus danicus* Löhnis and Westermann, Cent. f. Bakt., II Abt., *22*, 1908, 253; *Bacillus graveolens* Gottheil, Cent. f. Bakt., II Abt., *7*, 1901, 496 and 535; *Bacillus malabarensis* Löhnis and Pillai, Cent. f. Bakt., II Abt., *19*, 1907, 91; *Bacillus musculi* Stapp, Cent. f. Bakt., II Abt., *51*, 1920, 39; *Bacillus oxalaticus* Migula, Arb. a. d. bakt. Inst. d. Tech. Hochschule z. Karlsruhe, *1*, Heft, 1, 1894, 139; *Bacillus petasites* Gottheil, Cent. f. Bakt., II Abt., *7*, 1901, 535 (Lawrence and Ford, Jour. Bact., *1*, 1916, 273); *Bacillus ruminatus* Gottheil, *ibid.*, 496; *Bacillus silvaticus* Neide, Cent. f. Bakt., II Abt., *12*, 1904, 32; *Bacillus tumescens* Zopf, Die Spaltpilze, 1 Aufl., 1883, 66 (*Zopfiella tumescens* Trevisan, Car. d. alc. nuov. gen. di Batter., 1885, 4).

Other possible synonyms given by Neide (*loc. cit.*, 11): *Bacterium hirtum* Henrici, Arb. bakt. Inst. Karlsruhe, *1*, 1894, 44 (*Pseudomonas hirtum* Ellis, Cent. f. Bakt., II Abt., *11*, 1903, 243; *Bacillus hirtus* Ellis, Ann. Bot., *20*, 1906, 233); *Bacillus brassicae* Pommer, Mitt. botan. Inst. Graz, *1*, 1886, 95 (*Bacterium brassicae* Migula, Syst. d. Bakt., *2*, 1900, 296).

Although the name *Bacillus tumescens* Zopf (which is here regarded as a probable synonym) has priority over *Bacillus megatherium*, the latter name is preferred because of general usage. Neither of the original descriptions is sufficiently detailed to characterize adequately the

species named, and Zopf (Die Spaltpilze, 3 Aufl., 1885, 82–83) regarded the two species as distinct. The modern work on which the present description of *Bacillus megatherium* is based has been largely carried out with cultures identified as *Bacillus megatherium*, and the true nature of the species is really fixed by the informal emendations made in these more recent descriptions. The emended descriptions give this name a more certain meaning than is given *Bacillus tumescens* by the descriptions existent in the literature.

Spores: Ellipsoidal, sometimes nearly round, central to paracentral, 1.0 to 1.5 by 1.5 to 2.0 microns (larger dimensions have been reported).

Sporangia: Ellipsoidal to cylindrical, often in short chains; not swollen.

Rods: 1.2 to 1.5 by 2.0 to 4.0 microns, occurring singly and in short chains. Larger and smaller cells, irregular, twisted, and shadow forms are present in some strains, depending upon the substrate. Cells from glucose or glycerol nutrient agar usually store much fat and stain unevenly (vacuolated) with dilute stains. Motility with peritrichous flagella, usually slow, although some strains may show active motility. Gram-positive.

Gelatin stab: Slow liquefaction.

Agar colonies: Large, smooth, soft, convex, entire, opaque, creamy-white to yellow. The rough stage is usually concentrically ridged with a thin edge.

Agar slants: Growth abundant, soft, butyrous, creamy-white to yellow with pellucid dots. Browning with age; a few strains become black if the medium contains tyrosine.

Broth: Medium to heavy uniform turbidity.

Milk: Peptonized.

Milk agar plate: Casein hydrolyzed.

Potato: Growth abundant, smooth, soft to slimy, spreading, creamy-white, pale to lemon-yellow or pink. A few strains are orange-colored, some blacken the potato. The rough stage is wrinkled.

Nitrites usually not produced from nitrates.

Starch is hydrolyzed.

Acid with ammoniacal nitrogen from arabinose, glucose, fructose, sucrose, maltose, dextrin, inulin, salicin, glycerol and mannitol. Usually acid from xylose, galactose, mannose, and raffinose; variable from lactose. Generally no acid from rhamnose.

Acetylmethylcarbinol not formed.

Citrates used as sole source of carbon.

Uric acid hydrolysis: Variable.

Optimum temperature 28°C to 35°C. Maximum temperature allowing growth usually between 40°C and 45°C.

Source: Originally isolated from cooked cabbage.

Habitat: Widely distributed in soil, water, and decomposing materials.

NOTE: A description of *Bacillus megatherium—Bacillus cereus* intermediates follows the description of *Bacillus cereus*.

7. **Bacillus cereus** Frankland and Frankland. (Philosoph. Transact. Roy. Soc. London, *178*, B, 1887, 279.) From Latin *cereus*, waxy.

Synonyms: *Bacillus ellenbachensis alpha* Stutzer and Hartleb, Cent. f. Bakt., II Abt., *4*, 1898, 31; *Bacillus ellenbachensis* Gottheil, Cent. f. Bakt., II Abt., *7*, 1901, 540; *Bacterium petroselini* Burchard, Arb. bakt. Inst. Karlsruhe, *2*, 1898, 39 (*Bacillus petroselini* Lehmann and Neumann, Bakt. Diag., 4 Aufl., *2*, 1907, 414).

The following are given as possible synonyms by Gottheil, Cent. f. Bakt., II Abt., 7, 1901, 540: *Bacillus ramosus liquefaciens* Flügge, Die Mikroorganismen, 2 Aufl., 1886, 342; *Bacillus stoloniferus* Pohl, Cent. f. Bakt., *11*, 1892, 142 (*Bacterium stoloniferus* Chester, Ann. Rept. Del. Col. Agr. Exp. Sta., *9*, 1897, 91; *Achromobacter stoloniferum* Bergey et al., Manual, 1st ed., 1923, 136); *Bacillus limosus* Russell, Ztschr. f. Hyg., *11*,

1892, 196 (not *Bacillus limosus* Klein, Ber. d. deutsch. bot. Gesellsch., *7*, 1889, 65; *Bacillus limophilus* Migula, Syst. d. Bakt., *2*, 1900, 550); *Bacillus brevis o* Flügge, Ztschr. f. Hyg., *17*, 1894, 294; *Bacillus lutulentus* Kern, Arb. bakt. Inst. Karlsruhe, *1*, 1897, 402; *Bacillus goniosporus* Burchard, Arb. bakt. Inst. Karlsruhe, *2*, 1898, 14; *Bacterium turgescens* Burchard, *ibid.*, 18; *Bacillus cursor* Burchard, *ibid.*, 25; *Bacillus loxosus* Burchard, *ibid.*, 37.

The following are also listed as synonyms or biotypes of *Bacillus cereus* by Smith, Gordon and Clark: *Bacillus sessilis* Klein, Cent. f. Bakt., *6*, 1889, 349 and 377 (*Bacterium sessile* Migula, Syst. d. Bakt., *2*, 1900, 290); *Bacillus albolactis* Migula, *ibid.*, 577 (*Bacillus lactis albus* Loeffler, Berlin. klin. Wchnschr., 1887, 630); *Bacillus lacticola* Neide, Cent. f. Bakt., II Abt., *12*, 1904, 168 (Bacillus No. V, Flügge, Ztschr. f. Hyg., *17*, 1894, 294; *Bacillus lactis* No. V, Kruse, in Flügge, Die Mikroorganismen, 3 Aufl., *2*, 1896, 208; *Bacterium lacticola* Migula, Syst. d. Bakt., *2*, 1900, 305; *Bacillus excurrens* Migula, *ibid.*, 582; *Bacillus cereus* Chester, Man. Determ. Bact., 1901, 278; not *Bacillus cereus* Frankland and Frankland, Philos. Trans. Roy. Soc. London, *178*, B, 1887, 279); *Bacillus lactis* Neide, Cent. f. Bakt., II Abt., *12*, 1904, 337 (*Bacillus No. I*, Flügge, Ztschr. f. Hyg., *17*, 1894, 294; *Bacillus flüggei* Chester, Manual Determ. Bact., 1901, 281); *Bacillus robur* Neide, Cent. f. Bakt., II Abt., *12*, 1904, 18; *Bacillus thuringiensis* Berliner, Zeit. f. angew. Entomol., *2*, 1915, 29 (see also Mattes, Gesellschaft zur Beförd. der Gesam. Naturw., *62*, 1927, 381; *Bacterium thuringiensis* Chorine, Internat. Corn Borer Invest., *2*, 1929, 50); *Bacillus cereus* var. *fluorescens* Laubach, Jour. Bact., *1*, 1916, 508 (*Bacillus fluorescens* Bergey et al., Manual, 1st ed., 1923, 298; not *Bacillus fluorescens* Trevisan, I generi e le specie delle Batteriacee, 1889, 18); *Bacillus subtilis* Michigan strain, Conn., Jour. Inf. Dis., *46*, 1930, 341; *Bacillus undulatus* den Dooren de Jong, Cent. f. Bakt., I Abt., Orig., *122*, 1931, 277 (see also den Dooren de Jong, Arch. f. Mikrobiol., *4*, 1933, 36); *Bacillus siamensis* Siribaed, Jour. Inf. Dis., *57*, 1935, 143 (see also *Bacillus cereus* var. *siamensis* Clark, Jour. Bact., *33*, 1937, 435); *Bacillus metiens* Charlton and Levine, Iowa Eng. Exp. Station, Bull. 132, 1937, 18; (see also Levine, Buchanan and Lease, Iowa State Coll. Jour. Sci., *1*, 1927, 379); *Bacillus tropicus* Heaslip, Med. Jour. Australia, *28*, 1941, 536.

Neide (*loc. cit.*) gave the following as possible synonyms of *Bacillus lacticola: Bacillus butyricus* Hueppe, Mitteil. a. d. kaiserl. Gesundheitsamte, *2*, 1884, 309; not *Bacillus butyricus* Macé, Traité de Bact., 1st ed., 1888 (*Clostridium butyricum* Prazmowski, Untersuchungen über die Entwickelungsgeschichte und Fermentwirkung einiger Bacterien-Arten. Inaug. Diss., Leipzig, 1880, 23); *Bacillus aureus* Pansini, Arch. f. pathol. Anat. u. Physiol., *122*, 1890, 436 (not *Bacillus aureus* Frankland and Frankland, Philos. Trans. Roy. Soc. London, *178*, B, 1887, 272); *Bacillus lacteus* Migula, Syst. d. Bakt., *2*, 1900, 571 (No. 17, Lembke, Arch. f. Hyg., *29*, 1897, 323); *Bacillus goniosporus* Burchard, *loc. cit.*

Neide also gave the following as possible synonyms of *Bacillus lactis: Bacillus lutulentus* Kern, *loc. cit.*; *Bacillus agglomeratus* Migula, Syst. der Bakt., *2*, 1900, 557; *Bacillus amarificans* Migula, *ibid.*, 584; *Bacillus cylindrosporus* Burchard, Arb. bakt. Inst. Karlsruhe, *2* 1898, 31.

Other possible synonyms of *Bacillus cereus* are: *Bacillus anthracoides* Hüppe and Wood, Ber. klin. Wchnschr., *16*, 1889, 347 (Kruse, in Flügge, Die Mikroorganismen, 3 Aufl., *2*, 1896, 232; *Bacterium anthracoides* Migula, Syst. der Bakt., *2*, 1900, 281; not *Bacterium anthracoides* Trevisan, I generi e le specie delle Batteriacee, 1889, 20); *Bacillus pseudanthracis* Wahrlich, Bakteriol. Studien, Petersburg, 1890–91, 26 (not

Bacillus pseudanthracis Kruse, in Flügge, Die Mikroorganismen, 3 Aufl., *2*, 1896, 233; *Bacterium pseudoanthracis* Migula, *loc. cit.*, 282); *Bacterium flexile* Burchard, Inaug. Diss., Karlsruhe, 1897 and Arb. bakt. Inst. Karlsruhe, *2*, 1898, 16; *Bacillus ellenbachi* Sawamura, Tokyo Imp. Univ. Coll. Agr. Bull. *7*, 1906, 105; *Bacillus hoplosternus* Paillot, Compt. rend. Acad. Sci., Paris, *163*, 1916, 772; *Bacillus fulminans* Schrire and Greenfield, Trans. Roy. Soc. So. Africa, *17*, 1929, 309.

Spores: Ellipsoidal, average size 1.0 by 1.5 microns (considerable variation has been noted by various writers), central or paracentral, usually freely formed in 24 hours. Germination prevailingly polar.

Sporangia: Ellipsoidal or cylindrical, only slightly swollen, if at all. In short to long chains.

Rods: 1.0 to 1.2 by 3.0 to 5.0 microns, occurring in long chains, ends square. Cells appear granular or foamy if lightly stained, especially if grown on glucose or glycerol nutrient agar; fat usually stored. Smooth strains are motile with many peritrichous flagella, rough strains weakly motile or non-motile. Gram-positive.

Gelatin stab: Rapid liquefaction.

Agar colonies: Large, flat, entire or irregular, whitish with characteristic appearance by transmitted light described by various observers as ground glass, moire silk, or galvanized iron. All stages occur from the thin, spreading, very rough and arborescent, to the smooth dense form of colony.

Agar slant: Growth abundant, usually non-adherent, spreading, dense, whitish to slightly yellowish. Old slants show characteristic whip-like outgrowths. Some strains produce a yellowish-green fluorescence.

Broth: Heavy uniform turbidity, with or without a fragile pellicle.

Milk: Rapid peptonization, with or without slight coagulation.

Blood serum: Partially liquefied. Hemolysis on blood agar.

Potato: Growth abundant, thick, soft, creamy-white to pinkish, spreading over the potato. Rough strains may be folded and more pigmented.

Nitrites usually produced from nitrates.

Starch is hydrolyzed.

Acid (with ammoniacal nitrogen) from glucose, fructose, maltose, dextrin, and glycerol. Acid usually from sucrose and salicin. Usually no acid from mannose and lactose. No acid from arabinose, rhamnose, xylose, raffinose, inulin, and mannitol.

Acetylmethylcarbinol produced.

Citrates usually utilized as sole source of carbon.

Optimum temperature about 30°C. Maximum temperature allowing growth varies from 37°C to 48°C, usually about 43°C.

Aerobic.

Source: From soil, dust, milk, plants, and as contaminant of media.

Habitat: Widely distributed. Occurs more often in soil than any other member of the genus. See Chester, Del. Agr. Exp. Station, 15th Ann. Report, 1903, 73; Lawrence and Ford, Jour. Bact., *1*, 1916, 284; Conn, N. Y. Exp. Station, Tech. Bull. 58, 1917; Conn and Breed, Jour. Bact., *4*, 1919, 273; Soriano, Thesis, Univ. Buenos Aires, 1935, 569.

Bacillus megatherium—Bacillus cereus intermediates.

According to Smith, Gordon, and Clark (*loc. cit.*) intermediate forms occur between *Bacillus megatherium* and *Bacillus cereus* which cannot be represented by a distinct species. These intermediates are characterized morphologically by the early appearance on agar of shadow or distorted forms, long filaments, and generally only a few spores. Fat globules are smaller and less numerous. Physiologically the group is erratic, showing a progression of characters from *Bacillus megatherium* on the one hand to *Bacillus cereus* on the other. Acetylmethylcarbi-

nol and nitrites are not usually formed. Fermentation of the pentoses and mannitol, the ability to grow well on glucose nitrate agar, susceptibility to the bacteriophage active against *Bacillus megatherium* or *Bacillus cereus* and the general character of the growth determines whether the intermediate is more closely related to *Bacillus megatherium* or to *Bacillus cereus*.

Bacillus cohaerens Gottheil (Cent. f. Bakt., II Abt., *7*, 1901, 458 and 689) may be taken as a representative of this intermediate group resembling *Bacillus megatherium* more closely than *Bacillus cereus*. Gottheil gave as possible synonyms: *Bacillus vermicularis* Frankland and Frankland, Ztschr. f. Hyg., *6*, 1889, 384 (*Bacterium vermiculare* Migula, Syst. d. Bakt., *2*, 1900, 302); *Bacillus filiformis* Tils, Ztschr. f. Hyg., *9*, 1890, 293; *Bacillus lactis albus* Eisenberg, Bakt. Diag., 3 Aufl., 1891, 110; *Bacillus virgatus* Kern, Arb. bakt. Inst. Karlsruhe, *1*, 1897, 416; *Bacillus cylindrosporus* Burchard, Arb. bakt. Inst. Karlsruhe, *2*, 1898, 31; *Bacillus bipolaris* Burchard, *ibid.*, 34.

Other strains which apparently belong to this same group are: *Bacterium pansinii* Migula, Syst. d. Bakt., *2*, 1900, 303 (Bacillus No. 3, Pansini, Arch. f. path. Anat., *122*, 1890, 439; *Bacterium granulatum* Chester, Man. Determ. Bact., 1901, 189); *Bacterium tomentosum* Henrici, Arb. bakt. Inst. Karlsruhe, *1*, 1897, 40; *Bacillus teres* Neide, Cent. f. Bakt., II Abt., *12*, 1904, 161.

Representing those strains in this intermediate group more closely related to *Bacillus cereus* is *Bacillus simplex* Gottheil (*loc. cit.*, 685). Gottheil gave the following as possible synonyms: *Bacillus vacuolosis* Sternberg, Manual of Bact., 1893, 717; *Bacillus natans* Kern, Arb. bakt. Inst. Karlsruhe, *1*, 1897, 413; *Bacillus loxosporus* Burchard, Arb. bakt. Inst. Karlsruhe, *2*, 1898, 49.

7a. *Bacillus cereus* var. *mycoides* (Flügge) *comb. nov.* (*Bacillus mycoides* Flügge, Die Mikroorganismen, 2 Aufl., 1886, 324.) From Greek *mykes*, fungus; *eidos*, form, shape, i.e., fungus-like.

Gottheil, Cent. f. Bakt., II Abt., *7*, 1901, 589, gave the following as probable synonyms: Wurzelbacillus, Eisenberg, Bakt. Diag., 1st ed., 1886, 4; *Bacillus figurans* Crookshank, Manual, 1st ed., 1886 (*Bacterium figurans* Chester, Ann. Rept. Del. Col. Agr. Exp. Sta., *9*, 1897, 134); *Bacillus brassicae* Pommer, Mitt. a. d. botan. Inst. zu Graf, *1*, 1886, 95 (*Bacterium brassicae* Migula, Syst. d. Bakt., *2*, 1900, 296); *Bacterium casei* Migula, Syst. d. Bakt., *2*, 1900, 304 (Bacillus No. XVI, Adametz, Landw. Jahrb., *18*, 1889, 248; *Bacterium proteum* Chester, Man. Determ. Bact., 1901, 195); *Bacillus ramosus* Frankland and Frankland, Ztschr. f. Hyg., *6*, 1889, 388 (not *Bacillus ramosus* Veillon and Zuber, Arch. Méd. Exp. et Anat. Path., *10*, 1898, 542); *Bacillus radicosus* Zimmermann, Die Bakterien unserer Trink- u. Nutzwässer, etc., I Reihe, 1890, 30 (*Bacterium radicosum* Migula, Syst. d. Bakt., *2*, 1900, 283); *Bacillus implexus* Zimmermann, *ibid.* (*Bacterium implexum* Migula, *ibid.*, 298); *Bacillus intricatus* Migula, *ibid.*, 546 (*Cladothrix intricata* Russell, Ztschr. f. Hyg., *11*, 1892, 191).

Another possible synonym is *Bacillus praussnitzii* Trevisan (I generi e le specie delle Batteriacee, 1889, 20). Laubach, Jour. Bact., *1*, 1916, 495, found that this differed from *Bacillus mycoides* only in the fermentation of lactose. This has been substantiated by later work.

Holzmüller (Cent. f. Bakt., II Abt., *23*, 1909, 304) described four varieties of *Bacillus mycoides* which he designated by Greek letters and in addition named four new species which were apparently only variations of *Bacillus mycoides*: *Bacillus effusus*, *Bacillus olfactorius*, *Bacillus nanus* and *Bacillus dendroides* (not *Bacillus dendroides* Thornton, Ann. Appl. Biol., *9*, 1922, 247).

Bacillus cereus var. *mycoides* is identi-

cal in all respects with *Bacillus cereus* except in the following characters:

Agar colonies: Grayish, thin, widely spreading by means of long twisted chains of cells, turning to the right or left.

Agar slants: Growth thin, rhizoid, grayish, widely spreading, adhering to or growing into the agar. Later, growth becomes thicker and softer.

The physiological similarity between *Bacillus cereus* and *Bacillus mycoides* has often been noted. Gordon (Jour. Bact., *39*, 1940, 98) showed that the rhizoid character of the growth of *Bacillus mycoides* was readily lost by cultivation in flasks containing 100 ml of broth and that the resulting dissociants could not be differentiated from *Bacillus cereus*. It is, therefore, a question whether *Bacillus mycoides* should be given the dignity of a variety of *Bacillus cereus* or merely designated as a stage of growth (morphotype).

Source: Isolated from soil.

Habitat: Widely distributed in soil.

8. **Bacillus anthracis** Cohn *emend.* Koch. (Les infusories de la maladie charbonneuse, Davaine, Compt. rend. Acad. Sci., Paris, *69*, 1864, 393; Cohn, Beiträge z. Biol. d. Pflanzen, *1*, Heft 2, 1872, 177; Koch, *ibid.*, *2*, Heft 2, 1876, 279; Bactéridie des charbon, Pasteur and Joubert, Compt. rend. Acad. Sci., Paris, *84*, 1877, 900; *Bacterium anthracis* Zopf, Die Spaltpilze, 2 Aufl., 1884, 45; *Bacillus (Streptobacter) anthracis* Schroeter, Kryptogamen Flora v. Schlesien, *3*, 1, 1886, 163; *Pollendera anthracis* Trevisan, 1884, see Trevisan, I generi e le specie delle Batteriacee, 1889, 13; *Bacterium anthracis* Migula, in Engler and Prantl, Die natürlichen Pflanzenfam., *1*, 1a, 1895, 21; *Aplanobacter anthracis* Erw. Smith, Bacteria in Relation to Plant Diseases, 1905, 171; *Bacillus (Bacteridium) anthracis* Buchanan, Jour. Bact., *3*, 1918, 37.) From Greek, gen. of *anthrax*, charcoal, a carbuncle, the disease anthrax.

According to Smith, Gordon, and Clark (*loc. cit.*) this species is a pathogenic variety of *Bacillus cereus*. They worked extensively with the latter but not with many strains of *Bacillus anthracis*. The only difference between the two seemed to be pathogenicity and motility, and some strains of *Bacillus cereus* are weakly pathogenic and some practically non-motile. It would appear that *Bacillus cereus* is a so-called *parent species* from which two varieties (var. *anthracis* and var. *mycoides*) and several morpho- and biotypes have sprung.

Spores: Ellipsoidal, 0.8 to 1.0 by 1.3 to 1.5 microns, central or paracentral, often in chains. Germination polar.

Sporangia: Ellipsoidal to cylindrical, not swollen, in chains.

Rods: 1.0 to 1.3 by 3 to 10 microns with square or concave ends, occurring in long chains, resemble *Bacillus cereus*. Cells from glucose or glycerol nutrient agar appear granular (vacuolated) if stained lightly; many fat globules present. Non-motile. Gram-positive.

Gelatin stab: Arborescent in depth, inverted pine tree. Liquefaction crateriform becoming stratiform.

Agar colonies: Large, irregular, dense, curled structure composed of parallel chains, similar to certain strains of *Bacillus cereus*.

Agar slant: Growth abundant, grayish, dense, spreading, with fimbriate borders.

Broth: Little or no turbidity, thick pellicle.

Milk: Coagulated, slightly acid, peptonized.

Potato: Growth abundant, spreading, white to creamy.

Nitrites formed from nitrates.

Starch is hydrolyzed.

Acid from glucose, fructose, sucrose, maltose, trehalose, and dextrin. Some strains produce late and slight acidity in glycerol and salicin. No definite fermentation occurs in arabinose, rhamnose, mannose, galactose, lactose, raffinose, inulin, mannitol, dulcitol, sorbitol, inosi-

tol, and adonitol (Stein, Vet. Med., *38*, 1943).

Acetylmethylcarbinol produced.

Optimum temperature about 35°C. Maximum temperature allowing growth about 43°C.

Aerobic, facultative.

Pathogenic for man, cattle, swine, sheep, rabbits, guinea pigs, mice, etc.

Source: From blood of infected animals.

Habitat. The cause of anthrax in man, cattle, sheep and swine.

9. **Bacillus polymyxa** (Prazmowski) Migula. (*Clostridium polymyxa* Prazmowski, Inaug. Diss., Leipzig, 1880, 37; Migula, Syst. der Bakt., *2*, 1900, 638; *Granulobacter polymyxa* Beijerinck, K. Akad. Wetenschap., Amsterdam, Sec. 2, *1*, 1903, No. 10; *Granulobacter polymyxa* var. *mucosum* and var. *tenax* Beijerinck and Van Delden, Cent. f. Bakt., II Abt., *9*, 1902, 13; further description by Gruber, Cent. f. Bakt., II Abt., *14*, 1905, 353; *Aerobacillus polymyxa* Donkèr, *loc. cit.*, 138.) From Greek *poly*, many or much; *myxa*, slime or mucus.

This and the species immediately following (*Bacillus macerans*) are sometimes placed in the sub-genus *Aerobacillus* Donker *emend.* Kluyver and Van Neil (Donker, Inaug. Diss., Delft, 1926, 138; Kluyver and Van Neil, Cent. f. Bakt., II Abt., *94*, 1936, 402; not *Aerobacillus* Pribram, Jour. Bact., *18*, 1929, 374; not *Aerobacillus* Janke, Cent. f. Bakt., II Abt., *80*, 1930, 481).

For a study of this group and a review of the literature see Porter, McCleskey and Levine, Jour. Bact., *33*, 1937, 163. They give the following as synonyms of *Bacillus polymyxa: Bacillus asterosporus* Migula (*Astasia asterospora* Meyer, Flora, Erg. Bd., *84*, 1897, 185; Migula, Syst. der Bakt., *2*, 1900, 528; *Aerobacillus asterosporus* Donker, *loc. cit.*, 141); *Bacillus ovoaethylicus* Pribram (*Bacillus mycoides* var. *ovoaethylicus* Wagner, Ztschr. f. Untersuch. d. Nahrungs- u. Genussmittel, *31*, 1916, 234; Pribram, Klassifikation der Schizomyceten, Leipzig und Wien, 1933, 86); *Bacillus aerosporus* Greer, Jour. Inf. Dis., *42*, 1928, 508.

Gottheil (Cent. f. Bakt., II Abt., *7*, 1901, 727) regarded the following as synonyms: *Bacillus thalassophilus* Russell, Ztschr. f. Hyg., *11*, 1892, 190; *Bacillus subanaerobius* Migula, Syst. der Bakt., *2*, 1900, 600.

Bredemann (Cent. f. Bakt., II Abt., *23*, 1909, 45) admitted that the organisms, *Bacillus asterosporus alpha*, *Bacillus dilaboides*, and *Bacillus clostridioides*, named by Haselhoff and himself in an earlier article (Landwirtsch. Jahrb., *35*, 1906, 420, 426, 432) were merely variants of *Bacillus asterosporus*.

The following is usually considered a variety or strain of *Bacillus polymyxa* differing from the latter mainly in the production of a violet pigment on potato and agar in the presence of peptone: *Bacillus violarius acetonicus* Bréaudat, Ann. Inst. Pasteur, *20*, 1906, 874 (*Aerobacillus violarius* Donker, Inaug. Diss., Delft, 1926, 141).

Also a probable synonym of *Bacillus polymyxa* is *Bacillus amaracrylus* Voisenet (Bacille de l'amertume, Voisenet, Compt. rend. Acad. Sci., Paris, *153*, 1911, 363; Voisenet, Ann. Inst. Pasteur, *32*, 1918, 477; *Aerobacillus amaracrylus* Donker, *loc. cit.*, 141). The chief character in which it differs from *Bacillus polymyxa* is its ability to dehydrate glycerol with the formation of acrolein.

Also a probable variant of *Bacillus polymyxa* is *Bacillus pandora* Corbet (Jour. Bact., *19*, 1930, 321). The chief characters in which the latter differs from the former are the production of acid without gas from glucose and the lack of diastatic action.

Spores: Ellipsoidal, 1.0 to 1.5 by 1.5 to 2.5 microns, central to subterminal, wall usually thick and stainable. Freely formed.

Sporangia: Swollen, spindle-shaped (clostridia), sometimes clavate.

Rods: 0.6 to 1.0 by 2.5 to 6.0 microns,

occurring singly or in short chains. Cells contain small fat globules when grown on glucose nutrient agar. Motile with peritrichous flagella. Gram-variable.

Gelatin stab: Slow liquefaction. Hydrolysis of gelatin always positive by Frazier technic.

Agar colonies: Thin, inconspicuous, lobed, spreading over entire plate. Rough forms are round, whitish, and sometimes tough.

Agar slant: Growth scant to moderate, indistinct to whitish. On glucose agar, the growth is much heavier, raised, gummy, glistening; gas is formed.

Broth: Uniform to granular turbidity, flocculent to slimy sediment. Rough stage forms pellicle. Final pH of glucose broth cultures 5.2 to 6.8.

Milk: Not coagulated, gas usually formed.

Milk agar plate: Casein hydrolyzed.

Potato: Growth moderate to abundant, whitish to light tan, potato decomposed with formation of gas. Growth of rough stains is denser and heaped up.

Nitrites are produced from nitrates.

Starch is hydrolyzed. Crystalline dextrins are not produced.

Acid and gas (with ammoniacal nitrogen) from arabinose, xylose, glucose, fructose, galactose, mannose, maltose, sucrose, lactose, trehalose, cellobiose, raffinose, melezitose, dextrin, inulin, salicin, glycerol, and mannitol. Gum is also usually formed. Erythritol, adonitol, dulcitol and inositol not fermented. With organic nitrogen no acid or gas from rhamnose or sorbitol (Porter, McCleskey, and Levine, *loc. cit.*, also Tilden and Hudson, Jour. Bact., *43*, 1942, 530). This, however, could not be confirmed by Smith, Gordon, and Clark (*loc. cit.*) who found that acid and gas were produced from both carbohydrates.

Hemicellulose and pectin are attacked (Ankersmit, Cent. f. Bakt., I Abt., Orig., *40*, 1905, 100). In glucose broth, ethyl alcohol and butylene-glycol are produced also small amounts of acetone and butyl alcohol.

Acetylmethylcarbinol is produced.

Citrates usually not utilized as sole source of carbon.

Optimum temperature about 30°C. No growth at 42°C to 45°C; good growth at 20°C, slow at 13°C.

Not agglutinated by *Bacillus macerans* sera, results with homologous sera irregular (Porter, McCleskey, and Levine, *loc. cit.*).

Aerobic, facultative.

Source: First isolations were from grain, soil, and pasteurized milk.

Habitat: Widely distributed in water, soil, milk, feces, decaying vegetables, etc.

In addition see: Chester, Del. Agr. Exp. Station, 15th Ann. Report, 1903, 65; Wund, Cent. f. Bakt., I Abt., Orig., *42*, 1906, 193, 289, 385; Wahl, Cent. f. Bakt., II Abt., *16*, 1906, 489; Ritter, Cent. f. Bakt., II Abt., *20*, 1908, 21; Meyer, Cent. f. Bakt., I Abt., Orig., *49*, 1909, 305; Bredemann, Cent. f. Bakt., II Abt., *23*, 1909, 41; Virtanen and Kurstom, Biochem. Ztschr., *161*, 1925, 9; Stapp and Zycha, Arch. f. Mikrobiol., *2*, 1931, 493; Zycha, Arch. f. Mikrobiol., *3*, 1932, 194; Patrick, Iowa State Coll. Jour. Sci., *7*, 1933, 407.

10. **Bacillus macerans** Schardinger. (Rottebazillus 1, Schardinger, Wiener klin. Wochenschr., *17*, 1904, 207; Schardinger, Cent. f. Bakt., II Abt., *14*, 1905, 772; *Aerobacillus macerans* Donker, Inaug. Diss., Delft, 1926, 139; *Zymobacillus macerans* Kluyver and Van Niel, Cent. f. Bakt., II Abt., *94*, 1936, 402.) From Latin *macerans*, softening, macerating or retting.

Porter, McCleskey, and Levine, Jour. Bact., *33*, 1937, 163, regard the following as a synonym of *Bacillus macerans*: *Bacillus acetoethylicum* Northrup, Ashe, and Senior, Jour. Biol. Chem., *39*, 1919, 1 (*Aerobacillus acetoethylicus* Donker, *loc. cit.*).

The following is probably a variant of

Bacillus macerans: *Aerobacillus schuylkilliensis* Eisenberg, Jour. Amer. Water Works Assoc., *34*, 1942, 365. It is said to differ from *Bacillus macerans* in that sorbitol is not fermented, hydrogen sulfide is produced and gelatin is liquefied.

Spores: Ellipsoidal, 1.0 to 1.5 by 1.5 to 2.5 microns, terminal to subterminal; wall thick and stainable.

Sporangia: Swollen terminally, clavate.

Rods: 0.6 to 1.0 by 2.5 to 6.0 microns, occurring singly or in pairs, cells are larger on sugar media than on sugar-free media, and contain a few small fat globules. Motile. Gram-variable.

Gelatin stab: Liquefaction variable (see optimum temperature). Gelatin is hydrolyzed as determined by the Frazier technic (30°C).

Agar colonies: Small, thin, transparent to whitish, irregular, usually smooth.

Agar slant: Growth moderate, spreading, inconspicuous.

Broth: Turbid, slight sediment. In sugar broths some strains produce slime. Glucose broth cultures, pH 5.0 to 5.5.

Milk: Acid and gas. No visible peptonization.

Milk agar plate: Casein not hydrolyzed in one week; later usually slight hydrolysis.

Potato: Growth indistinct, gas is formed and the potato is digested. Fruity odor sometimes produced.

Nitrites produced from nitrates.

Starch is hydrolyzed.

Acid and gas from arabinose, rhamnose, xylose, glucose, fructose, galactose, mannose, sucrose, maltose, lactose, trehalose, cellobiose, raffinose, melezitose, dextrin, inulin, salicin, pectin, xylan, glycerol, mannitol, and sorbitol. Erythritol, adonitol, dulcitol, and inositol not fermented (Porter, McCleskey, and Levine, *loc. cit.*).

Produces acetone and ethyl but never butyl alcohol; ratio acetone to alcohol is 1:2.

Acetylmethylcarbinol not produced.

Citrates not utilized as sole source of carbon.

Optimum temperature about 37°C. Good growth at 42° to 45°C and sometimes slightly higher; poor growth, if any, at 20°C.

Differentiated from *Bacillus polymyxa* by the production of crystalline dextrins from starch, lack of formation of acetylmethylcarbinol, and by growth at 42°C to 45°C.

All strains agglutinated by homologous sera but not by *Bacillus polymyxa* serum.

Aerobic, facultative.

For additional literature, see Porter, McCleskey and Levine, Jour. Bact., *33*, 1937, 180.

Source: Originally isolated from vats in which flax was retting.

Habitat: Widely distributed in soil, water, decomposing starchy materials, retting flax, etc.

11. **Bacillus circulans** Jordan. (Jordan, Exp. Inv., Mass. State Board Health, Part II, 1890, 831; *Bacterium circulans* Chester, Ann. Rept. Del. Col. Agr. Exp. Sta., *9*, 1897, 92; also see Ford, Jour. Bact., *1*, 1916, 519.) From Latin *circulans*, making round or circular.

Smith, Gordon, and Clark (*loc. cit.*) consider *Bacillus circulans* as a complex (see also Gibson and Topping, Soc. Agric. Bact. (British), Abstr. Proc., 1938, 43) because of the variations in the character of the growth and quantitative differences in physiology. All stages of growth may be found from the smooth actively motile strains that have motile colonies to the mucoid, non-spreading strains. The species is more saccharolytic than proteolytic, considerable variation being found in its action on gelatin and casein. The following are regarded as variants: *Bacillus closteroides* Gray and Thornton, Cent. f. Bakt., II Abt., *73*, 1928, 93; Bewegungstypus schwarmender Bakterien, Russ-Munger, Cent. f. Bakt., I Abt., Orig., *142*, 1938, 175; *Bacillus krzemieniewski*

Kleczkowska, Norman and Snieszko, Soil Sci., *49*, 1940, 185 (a mucoid variant).

Also probable variants: *Bacillus platus* Soriano, Thesis, Univ. Buenos Aires, 1935, 572; *Bacillus naviformis* Soriano, *ibid.*, 574 (not *Bacillus naviformis* Jungano, Comp. rend. Soc. Biol., Paris, *1*, 1909, 122).

Spores: Ellipsoidal, 0.8 to 1.2 by 1.1 to 2.0 microns, terminal or subterminal. Spore wall thick and stainable. In some strains spores may be kidney-shaped and remnants of sporangium may adhere.

Sporangia: Swollen terminally, clavate.

Rods: 0.5 to 0.9 by 2.0 to 5.0 microns, sometimes curved, usually occurring singly. Cells contain small fat globules when grown on glucose agar. Motile, some strains exceedingly so. Gram-variable, usually negative.

Gelatin stab: Slow cone-shaped liquefaction, liquefied portion evaporating (Jordan); no liquefaction (Ford). Gelatin hydrolyzed if tested by the Frazier method.

Agar colonies: Thin, transparent, spreading over entire surface of plate. Often nearly invisible. The colonies of the rougher or mucoid strains are small, entire, whitish, non-spreading.

Giant agar colonies: If the surfaces of agar plates are dried before inoculation with very motile strains, instead of spreading as a thin layer of individual cells, minute rotating colonies proceed out from the edge of the colony, sometimes becoming entirely disconnected from it. In moving out across the agar surface, non-motile cells are left behind. These may grow later. Eventually the whole plate is covered.

Agar slant: Growth thin, transparent, spreading, becoming denser. Mucoid strains are dense, non-spreading, entire, gummy and adherent.

Broth: Light to fair turbidity with flocculent to slimy sediment. Some strains do not grow perceptibly. In glucose broth cultures the final pH is usually 5.0 to 5.8.

Milk: Usually acid, slowly coagulated.

Milk agar plate: Casein not hydrolyzed. Weak hydrolysis with some strains.

Potato: Growth is very variable, from none to good growth, from colorless to yellowish, pink, or brownish.

Nitrites usually produced from nitrates.

Starch is hydrolyzed. Crystalline dextrins usually not formed.

Acid without gas (with ammoniacal nitrogen) from glucose, fructose, mannose, galactose, sucrose, maltose, raffinose, salicin, and dextrin. Usually acid from arabinose, xylose, lactose, glycerol, and mannitol. Reaction variable with rhamnose and inulin.

Acetylmethylcarbinol not produced.

Citrates usually not utilized.

Methylene blue reduced and then reoxidized.

Urease produced by some strains.

Optimum temperature about 30°C. Maximum temperature allowing growth, 40°C to 48°C. A few strains will grow up to 52°C.

This species is closely related to *Bacillus macerans* from which it is distinguished by the lack of gas formation from carbohydrates and the lack of crystalline dextrins from starch. It is also close to *Bacillus alvei* as indicated by the key.

Source: Found occasionally in tap water, Lawrence, Mass. (Jordan).

Habitat: Widely distributed in soil, water, and dust.

12. **Bacillus alvei** Cheshire and Cheyne. (Jour. Roy. Mic. Soc., Ser. II, *5*, 1885, 592.) From Latin *alveus*, beehive.

Probably identical with the above: *Bacillus paraalvei* Burnside, Amer. Bee Jour., *72*, 1932, 433; Burnside and Foster, Jour. Econ. Entomol., *28*, 1935, 578.

Spores: Ellipsoidal, 0.7 to 1.0 by 1.5 to 2.5 microns, central to terminal. Free spores frequently lie in parallel arrangement like the rods.

Sporangia: Swollen, spindle-shaped to clavate.

Rods: 0.5 to 0.8 by 2 to 5.0 microns. Cells frequently lie parallel, side by side, like cartridges in a clip. Usually non-capsulated and very motile. Few small fat globules in cells from glucose agar. Gram-variable (young cells Gram-positive, becoming Gram-negative).

Gelatin stab: Slow liquefaction.

Agar colonies: Thin, translucent, smooth, quickly spreading as a thin layer over entire plate. The growth thickens with age. Rough and mucoid strains do not spread.

Giant agar colonies: If the surfaces of agar plates are dried before inoculation with the motile strains, instead of spreading as a thin layer, minute bullet-shaped colonies proceed out from the edge of the colony and move across the sterile agar. Non-motile and sometimes motile cells are left behind along the path made by the motile colony (Smith and Clark, Jour. Bact., *35*, 1938, 59). Eventually the whole plate is covered.

Agar slant: Growth thin, inconspicuous, spreading, becoming thicker. Rough and mucoid strains do not spread, growth is heaped, and sometimes gummy.

Broth: Uniform turbidity. Rough strains may form a pellicle. Glucose broth cultures have a pH of 5.0 to 6.0.

Milk: Usually coagulated, little or no acid, peptonized.

Milk agar plate: Casein hydrolyzed.

Potato: Growth scant to moderate, soft, spreading, usually creamy yellow.

Nitrites not produced from nitrates.

Starch is hydrolyzed.

Acid (with ammoniacal nitrogen) from glucose, fructose, galactose, sucrose, maltose, dextrin and glycerol. Reaction variable on mannose, lactose, raffinose, salicin, and mannitol. No acid from arabinose, rhamnose, xylose, and inulin.

Acetylmethylcarbinol is produced.

Citrates not utilized.

Optimum temperature about 30°C. Maximum temperature allowing growth 43°C to 45°C.

Putrefactive odor on media rich in proteins (egg).

Aerobic.

Source: Isolated from diseased brood of bees.

Habitat: Associated with European foulbrood of honey bees; widely distributed in soil.

NOTE: The following must be considered in connection with *Bacillus alvei*:

Bacillus pluton White. (U. S. Dept. of Agric., Bur. Entomol., Circ. 157, 1912; *Diplococcus pluton* Bergey et al., Manual, 2nd ed., 1925, 45.)

See also Lochhead, Science, *67*, 1928, 159 and Proc. IV Intern. Congr. Entomol., *2*, 1929, 1005; Burnside, Jour. Econ. Entomol., *27*, 1934, 656; Tarr, Ann. Appl. Biol., *24*, 1935, 614; Burri, Beihefte z. schweiz. Beinenz., *1*, Heft 1, 1941.

White considered *Bacillus pluton* to be the cause of European foulbrood though the evidence was indirect since the organism was not cultivated. Lochhead suggested that *Bacillus pluton* and *Streptococcus apis* are variants or stages in the life history of *Bacillus alvei*, a hypothesis supported by Burnside who included, in addition, *Bacterium eurydice*. According to Burri, rod forms identical with *Bacterium eurydice* give rise to *Bacillus pluton* which is not directly cultivable. Tarr considers European foulbrood to be caused by *Bacillus pluton*, distinct from *Bacillus alvei*, and considers it a strict parasite able to multiply only in the intestines of young larvae.

Source: Larvae of the honey bee infected with European foulbrood.

13. **Bacillus laterosporus** Laubach. (Jour. Bact., *1*, 1916, 511.) From Latin *latus*, *lateris*, the side; Greek *sporus*, seed; M.L., spore.

Synonym: *Bacillus orpheus* White. (U. S. Dept. of Agric., Bur. Entomol., Circ. 157, 1912, 3.) Although named by White, the organism was not described

until 1917 (McCray, Jour. Agr. Research, 8, 1917, 410). Resembles *Bacillus laterosporus* (White, U. S. Dept. Agric. Bull. 810, 1920, 14). According to the rules of priority, the name to be used is *Bacillus laterosporus*.

Spores: Ellipsoidal, 1.0 to 1.3 by 1.2 to 1.5 microns, central to subterminal, formed close to one side, remnants of the sporangium adhering to the other side.

Sporangia: Swollen, spindle-shaped.

Rods: 0.5 to 0.8 by 2.0 to 5.0 microns, occurring singly and in pairs. Ends pointed or poorly rounded. Cells from glucose nutrient agar may have few small fat globules. Motile. Gram-variable.

Gelatin stab: Slow liquefaction.

Agar colonies: Thin, transparent, irregular, spreading. Colonies of rough strains are small, round, convex, non-spreading.

Agar slant: Growth moderate, flat, translucent to opaque, moist, sometimes with a silvery sheen.

Broth: Uniform to granular turbidity; usually no pellicle. Glucose broth cultures, pH 6.0 to 6.4.

Milk: Usually curdled, peptonized.

Milk agar plate: Occasionally weak hydrolysis of casein.

Potato: Growth thin, spreading, grayish to pinkish, turning light brown with age. Sometimes finely wrinkled.

Nitrites produced from nitrates.

Starch is not hydrolyzed.

Acid (with ammoniacal nitrogen) from glucose, fructose, maltose, glycerol, and mannitol. Reaction variable on galactose, mannose, and salicin. No acid from arabinose, rhamnose, xylose, sucrose, lactose, raffinose, inulin, and dextrin.

Acetylmethylcarbinol not produced.

Citrates not utilized as sole source of carbon.

Optimum temperature about 28°C. Maximum temperature allowing growth 37°C to 45°C.

Aerobic.

Source: Isolated from water.

Habitat: Widely distributed in soil, water and dust.

14. **Bacillus brevis** Migula *emend.* Ford. (Bacillus No. I, Flügge, Ztschr. f. Hyg., *17*, 1894, 294; *Bacillus lactis* No. I, Kruse, in Flügge, Die Mikroorganismen, 3 Aufl., *2*, 1896, 208; Migula, Syst. d. Bakt., *2*, 1900, 583; not *Bacillus brevis* Frankland and Frankland, Microorganisms in Water, 1894, 429; *Bacillus flüggei* Chester, Man. Determ. Bact., 1901, 281; Ford, Jour. Bact., *1*, 1916, 522.) From Latin *brevis*, short.

Synonym: *Bacillus centrosporus* Ford, Jour. Bact., *1*, 1916, 524.

There is some doubt as to the identity of Migula's *Bacillus brevis* which originally was Flügge's Bacillus No. I. Neide (Cent. f. Bakt., II Abt., *12*, 1904, 337) also renamed Flügge's organism. He called it *Bacillus lactis* and described it sufficiently that it may be recognized as a strain of *Bacillus cereus*. Ford believed that his isolations from milk, soil and dust conformed to Migula's description of *Bacillus brevis*. Ford's interpretation has been accepted. The species has apparently become well established in Europe (Gibson and Topping, Soc. Agric. Bact. (British), Abstr. Proc., 1938, 43) as well as in America.

Description from Ford and from Smith, Gordon, and Clark (*loc. cit.*).

Spores: Ellipsoidal, 1.0 to 1.3 by 1.5 to 2.0 microns, central to subterminal. Spore walls thick and stainable. An occasional strain shows the relationship of this species to *Bacillus laterosporus* in that some of the spores may be lateral and remnants of the sporangia may adhere to one side of the spore.

Sporangia: Definitely swollen, spindle-shaped to clavate.

Rods: 0.4 to 0.8 by 1.5 to 5.0 microns, with pointed ends, occurring singly or in pairs. On glucose agar cells contain numerous small fat globules. Motile. Gram-variable.

Gelatin stab: Slow liquefaction.

Agar colonies: Thin, flat, translucent, smooth, quickly spreading over plate.

Agar slants: Growth smooth, moist, spreading, grayish white.

Broth: Usually heavy uniform turbidity, sometimes with a fragile pellicle. Glucose broth cultures have a pH of 8.0 to 8.6 after 7 days.

Milk: Peptonized.

Milk agar plate: Casein hydrolyzed.

Potato: Growth scant to moderate, flat, spreading, soft, creamy-yellow to pink to brownish.

Nitrites usually formed from nitrates.

Starch is not hydrolyzed.

Acid (with ammoniacal nitrogen) from glucose, fructose, maltose, and sucrose. Usually acid from galactose and glycerol. Reaction is variable on rhamnose and mannitol. No acid from arabinose, xylose, mannose, lactose, raffinose, inulin, dextrin and salicin.

With organic nitrogen, the acid formed from carbohydrates is masked by the alkalinity due to proteolysis.

Acetylmethylcarbinol is not produced.

Citrates usually utilized as a sole source of carbon.

Optimum temperature about 30°C. Maximum temperature allowing growth varies from 43°C to 54°C.

Produces antibiotic substances (tyrothricin, gramicidin; see Dubos and Hotchkiss, Jour. Exp. Med., *73*, 1941, 629).

Aerobic.

Source: From milk (Flügge); from milk, soil and dust (Ford).

Habitat: Widely distributed in soil, water, dust, milk, etc.

15. **Bacillus larvae** White. (Bacterium X, Moore and White, New York State Dept. Agr., 11th Ann. Rept. Com. Agr. for 1903, 1904, 111; Bacillus X, Moore and White, *ibid.*, Rept. for 1904, 1905, 106; White, Thesis, Cornell Univ., Ithaca, N. Y., 1905; White, U. S. Dept. Agr. Bur. Entomol., Tech. Ser. Bul. 14, 1906, 32; White, U. S. Dept. Agr. Bul. 809, 1920, 13.) From Latin *larva*, a ghost; M. L., of a larva.

Synonyms: *Bacillus brandenburgiensis* Maassen, Mittl. a. d. kaiserl. biol. Anstalt f. Land- u. Forstw. in Dahlem, Heft 2, 1906, 28; *ibid.*, Heft 7, 1908, 24 pp.; Arb, a. d. Anstalt f. Land- u. Forstw., *6*, 1908. 61; *Bacillus burri* Cowan, British Beekeeper's Guide Book. 20th ed., London, 1911, 171.

Description from Lochhead, Sci. Agr., *9*, 1928, 84.

Spores: Ellipsoidal, central to subterminal.

Sporangia: Swollen, spindle form.

Rods: 0.5 to 0.8 by 2.5 to 5.0 microns, occurring singly and in chains. Motile. Gram-variable.

Gelatin stab: No growth. In carrot-gelatin, slow liquefaction.

Yeast-carrot agar colonies: Small, whitish, somewhat transparent, smooth, slightly glistening.

Agar slant: No growth. With addition of carrot extract, noticeable growth along line of inoculation. More abundant growth if yeast extract is also added.

Yeast-carrot broth: Fungoid in appearance, floating masses which may be broken up by shaking to produce a uniform clouding.

Carrot-milk: Acid with curdling. No peptonization.

Potato: No growth.

Nitrites formed from nitrates (see Lochhead, Can. Jour. Res., C, *15*, 1937, 79).

Starch not hydrolyzed (carrot-starch agar).

Acid (in yeast extract-peptone broth) from xylose, glucose, fructose, galactose, salicin. Slight acidity by some strains from lactose and sucrose. No acid from mannitol or dulcitol.

Thiamin replaces the growth factor in vegetable or yeast extracts, etc. (Lochhead, Jour. Bact., *44*, 1942, 185).

Optimum temperature about 37°C. Maximum temperature about 45°C.

Source: From diseased brood.

Habitat: Causal organism of American foulbrood of honey bees.

See in addition: White, Science, *49*, 1919, 362; Sturtevant, Jour. Agr. Res., *28* 1924, 129; Borchert, Die seuchenhaften Krankheiten der Honigbiene. Berlin,

1926; Sturtevant, Jour. Agr. Res., *45*, 1932, 257; Hitchcock, Jour. Econ. Entomol., *29*, 1936, 895; Stoilowa, Cent. f. Bakt., II Abt., *99*, 1938, 124; Tarr, Ann. Appl. Biol., *25*, 1938, 633; Holst and Sturtevant, Jour. Bact., *40*, 1940, 723.

16. **Bacillus popilliae** Dutky. (Jour. Agr. Research, *61*, 1940, 59.) From the genus name of the Japanese beetle, *Popillia japonica* Newm.

Spores: Cylindrical, 0.9 by 1.8 microns, central. Free spores have not been observed.

Sporangia: Swollen, spindle-shaped. Contains a refractile body at the broader pole of the cell which is about half the size of the spore and reacts similarly to stains.

Rods: Unstained, 0.9 by 5.2 microns. Stained by crystal violet after fixing in Schaudinn's solution, 0.3 by 3.5 microns. Non-motile. Gram-positive.

Unheated egg yolk-beef infusion agar slants: Growth occurs as small discrete colonies.

Optimum temperature about 30°C. Maximum temperature about 36°C.

Aerobic, facultative.

Source: From infected larvae.

Habitat: Cause of type A milky disease of Japanese beetle, *Popillia japonica*. See Hawley and White, N. Y. Ent. Soc. Jour., *43*, 1935, 405.

17. **Bacillus lentimorbus** Dutky. (Jour. Agr. Res., *61*, 1940, 65.) From Latin *lentus*, slow, lingering, and *morbus*, death.

Spores: Ellipsoidal, 0.9 by 1.8 microns, central.

Sporangia: Swollen, spindle-shaped. No refractile granule at pole.

Rods: Unstained, 1.0 by 5.0 microns. Stained by crystal violet after fixing in Schaudinn's solution, 0.5 by 4.0 microns. No growth on artificial media.

Optimum temperature about 25°C. Maximum temperature about 30°C.

Aerobic, facultative.

Source: Diseased larvae.

Habitat: Cause of type B milky disease of Japanese beetle, *Popillia japonica*.

18. **Bacillus sphaericus** Neide. (Cent. f. Bakt., II Abt., *12*, 1904, 350.) From Latin *sphaericus*, spherical.

Neide (*loc. cit.*) gave the following as possible synonyms: *Bacillus (Streptobacter) albuminus* Schroeter, in Cohn, Kryptogamenflora von Schlesien, *3*, 1, 1886, 162; *Bacillus putrificus coli* Flügge, Die Mikroorganismen, 2 Aufl., 1886, 303; *Bacillus gracilis* Zimmermann, Die Bakterien unserer Trink- u. Nutzwässer, etc., *1*, 1890, 50 (*Bacterium gracile* Chester, Man. Determ. Bact., 1901, 198); *Bacillus butyricus* Botkin, Ztschr. f. Hyg., *11*, 1892, 421; *Bacillus thalassophilus* Russell, Ztschr. f. Hyg., *11*, 1892, 190; *Bacillus pseudotetanicus aerobius* Kruse, in Flügge, Die Mikoorganismen, 3 Aufl., *2*, 1896, 267 (*Bacillus pseudotetanicus* Migula, Syst. der Bakt., *2*, 1900, 626; not *Bacillus pseudotetanicus* Kruse, *idem;* not *Bacillus pseudotetanicus* Chester, Man. Determ. Bact., 1901, 302; *Bacillus pseudotetanicus* var. *aerobius* Chester, *ibid.*, 303); *Plectridium paludosum* Fischer, Jahr. f. Wiss. Bot., *27*, 1895, 147; Pseudotetanicusbacillus, Tavel, Cent. f. Bakt., I Abt., *23*, 1898, 538 (*Bacillus pseudotetani* Migula, Syst. der Bakt., *2*, 1900, 598; *Bacillus taveli* Chester, *loc. cit.*, 304).

Also apparently identical with *Bacillus sphaericus: Bacillus subtetanicus* Migula, Syst. der Bakt., *2*, 1900, 629; *Bacillus lactimorbus* Jordan and Harris, Jour. Amer. Med. Assoc., *50*, 1908, 1669 (see also Jour. Inf. Dis., *6*, 1909, 465); *Bacillus serositidis* Lacorte, Memorias do Instit. Oswaldo Cruz, *26*, 1932, 1.

There has been considerable confusion over the correct name to be applied to the non-pathogenic aerobic organisms resembling *Clostridium tetani*. Kruse (*loc. cit.*) isolated his cuture of *Bacillus pseudotetanicus aerobius* from a case of human tetanus. It was aerobic at ordinary temperatures but produced spores

only at higher temperatures and under anaerobic conditions. Migula called this *Bacillus pseudotetanicus*. Ford (Jour. Bact., *1*, 1916, 520) stated that this name had priority over Neide's *Bacillus sphaericus* which he thought was identical. On the other hand, Tavel (*loc. cit.*) isolated a pseudotetanus bacillus that was apparently anaerobic. Its spores were ellipsoidal and it formed more gas than the tetanus bacillus. Migula named this organism *Bacillus pseudotetani*. Subsequently both of Migula's names have been applied to the aerobic organism. *Bacillus pseudotetanicus* and *Bacillus pseudotetani* are *nomina dubia* and *Bacillus sphaericus* should therefore be used.

Spores: Spherical, 0.7 to 1.3 microns in diameter, terminal to subterminal. Young spores in sporangia may be oval. Spore wall thick; remnants of sporangium may adhere.

Sporangia: Definitely swollen, clavate to spindle-shaped.

Rods: 0.6 to 1.0 by 1.5 to 7.0 microns, occurring singly or in short chains. On glucose agar cells contain few small fat globules. Motile. Gram-variable; often Gram-negative with Gram-positive granules.

Gelatin stab: Scant growth. No liquefaction. Gelatin hydrolyzed if tested by the Frazier technic.

Agar colonies: Small, thin, flat, translucent, often spreading over the plate.

Giant agar colonies: If the surface of the agar is fairly dry, many strains exhibit minute colonies that swarm out from the point of inoculation and cover the plate (cf. *Bacillus alvei* and *Bacillus circulans*).

Agar slants: Growth thin, smooth, spreading, translucent, becoming yellowish-brown. Growth occurs at pH 6.0.

Broth: Uniform turbidity. Glucose broth cultures have pH of 8.3 to 8.6 after 7 days.

Milk: No change.

Milk agar plate: Scant, if any, hydrolysis of casein.

Potato: Growth scant, thin, spreading, soft, gray, becoming yellowish-brown with age.

Nitrites not formed from nitrates.

Starch not hydrolyzed.

No acid from carbohydrates.

Acetylmethylcarbinol not produced.

Citrates not utilized.

Urease not formed.

Salt tolerant. Growth occurs in broth containing 4 per cent NaCl.

Optimum temperature about 30°C. Maximum temperature allowing growth 40°C to 45°C.

Not pathogenic for guinea pigs.

Aerobic, facultative.

Source: From mud of a pond, rotting cypress wood, rotting oak wood, and from soil.

Habitat: Widely distributed in nature.

Bacillus rotans Roberts (Jour. Bact., *29*, 1935, 229) differs from *Bacillus sphaericus* in that it will not grow as low as pH 6.0 nor in broth containing 4 per cent NaCl. Originally characterized by motile colonies, this phenomenon has been noted with certain other members of the genus and with some strains of *Bacillus sphaericus*. Smith, Gordon, and Clark (*loc. cit.*) consider it a variety of *Bacillus sphaericus*.

Source: From intestine of a termite.

Habitat: Probably widespread in soil.

18a. *Bacillus sphaericus* var. *fusiformis comb. nov.* (*Bacillus fusiformis* Gottheil, Cent. f. Bakt., II Abt., *7*, 1901, 724.) From Latin *fusus*, spindle; *formis*, shape.

This organism differs from *Bacillus sphaericus* only in that it produces urease.

Source: One strain isolated from *Beta vulgaris lutea* (beet). Also from milk, dust, soil and contaminated hirudin.

Habitat: Widely distributed in nature.

Bacillus loehnisii Gibson (Jour. Bact., *29*, 1935, 495) is very closely related to the above. It will not grow at pH 6.0 or below, prefers media containing urea, and produces nitrites from nitrates. Gibson (*loc. cit.*, 500) in discussing the

organisms of this group stated "each species contains strains dissimilar in several features and each is connected to the others by transitional forms". Smith, Gordon, and Clark (*loc. cit.*) tentatively have placed it as a variety of *Bacillus sphaericus*.

Source: From soil.

Habitat: Widely distributed in soil.

19. **Bacillus pasteurii** (Miquel) Chester. (*Urobacillus pasteurii* Miquel, Ann. Micrographie, *1*, 1889, 552; sive *Bacillus ureae α, ibid.*, *2*, 1890, 13, 53, 122, 145, 367, 488; Chester, Ann. Rept. Del. Col. Agr. Exp. Sta., *10*, 1898, 110.) Named for the French scientist, Louis Pasteur (1822–1895).

Viehover, Cent. f. Bakt., II Abt., *39*, 1913, 209, gave the following as possible synonyms: *Urobacillus maddoxii* Miquel, Ann. Micrographie, *3*, 1891, 275 and 305 (*Bacterium maddoxi* Chester, Ann. Rept. Del. Col. Agr. Exp. Sta., *9*, 1897, 98; *Bacillus maddoxi* Chester, *ibid.*, *10*, 1898, 110); *Urobacillus leubei* Beijerinck, Cent. f. Bakt., II Abt., *7*, 1901, 51.

Synonyms according to Gibson, Jour. Bact., *29*, 1935, 494 and 496: *Bacillus probatus* Viehover, Cent. f. Bakt., II Abt., *39*, 1913, 209; *Urobacillus psychrocartericus* and *Urobacillus hesmogenes* Rubentschik, Cent. f. Bakt., II Abt., *66*, 1925, 166 (*Bacillus psychrocartericus* and *Bacillus hesmogenes* Bergey et al., Manual, 3rd ed., 1930, 403, 404). Gibson also included the following as possibly identical with the above although they were incompletely described: *Bacillus ureae II* and *III* Burri, Herfeldt and Stutzer, Jour. Landw., *42*, 1894, 329; *Urobacillus duclauxii* Miquel, Ann. Micrographie, *2*, 1890, 53, 122, and 145; *Urobacillus maddoxii* Miquel, *ibid.*, *3*, 1891, 275 and 305.

Description taken from Löhnis and Kuntze, Cent. f. Bakt., II Abt., *20*, 1908, 684; Gibson, Jour. Bact., *28*, 1934, 295 and 313; Smith, Gordon, and Clark (*loc. cit.*).

This species has been designated as the type species of the genus *Urobacillus* Miquel (Ann. de. Micrographie, *1*, 1889, 517) by Enlows (U. S. Pub. Health Ser., Hyg. Lab. Bull. 121, 1920, 96).

Spores: Spherical, 1.0 to 1.2 microns, terminal to subterminal.

Sporangia: Prevailingly clavate. Not in chains.

Rods: 0.7 to 0.8 by 1.5 to 2.0 microns (1.0 to 1.5 by 4.0 to 5.0 microns, Löhnis and Kuntze), occurring singly or in pairs. Motile. Gram-variable.

Urea gelatin stab: Slow liquefaction.

Urea agar colonies: Small, entire, not characteristic.

Urea agar slope: Growth thin, very little spreading, colorless or white to yellowish. Will not grow at pH 6.0 or less.

Urea broth: Moderate to heavy uniform turbidity. Will grow with 4 per cent NaCl added.

Nitrites produced from nitrates in urea nitrate nutrient broth.

Starch not hydrolyzed.

Carbohydrates not attacked.

Acetylmethylcarbinol not formed.

Urease produced.

Optimum temperature about 30°C, minimum 6°C. Maximum temperature allowing growth 40°C in water bath. Optimum temperature for urease activity 50°C.

Aerobic.

The distinguishing character of this species is that growth occurs only in peptone media containing urea or free ammonia under neutral or alkaline conditions.

Source: From decomposing urine.

Habitat: Widely distributed in soil, dust, manure, and sewage.

20. **Bacillus thermoamylolyticus** Coolhaas. (Cent. f. Bakt., II Abt., *75*, 1928, 344.) From Greek *thermos*, hot, *amylon*, starch, and *lytikos*, able to loose; hence, dissolving. Probably intended to mean thermophilic and starch digesting.

Spores: Slightly elongated, ellipsoids 0.6 by 1.5 microns, central.

Sporangia: Cylindrical, not swollen, not in chains.

Rods: 0.6 by 5 to 8 microns. Motile. Gram-positive.

Gelatin stab: No liquefaction.

Agar colonies: At 60°C of two types, large and small, circular, translucent, granular, slimy.

Broth: Very weak growth, no surface growth, no sediment.

Milk: Not coagulated, slowly peptonized.

Potato: Slight growth.

Nitrites produced from nitrates.

Starch actively hydrolyzed.

Acid and gas from glucose, fructose, galactose, maltose, dextrin, starch and glycerol. Arabinose, xylose and mannitol not fermented

Thermophilic, optimum temperature 50° to 55°C.

Aerobic.

Source: From sewage.

Habitat: Probably in decaying matter.

21. **Bacillus kaustophilus** Prickett. (N. Y. Agr. Exp. Sta. Tech. Bul. 147, 1928, 38.) From Greek *kaustós*, burnt, red-hot; *philos*, loving; heat-loving.

Spores: Ellipsoidal, 0.5 by 0.6 to 0.8 micron, terminal to subterminal. No free spores observed.

Sporangia: Only slightly swollen if at all.

Rods: On yeast extract-nutrient agar at 56°C, 0.7 by 2.0 to 4.5 microns, with rounded ends. Actively motile. Gram-positive.

Gelatin stab: No growth at 20°C. Liquefied at 56°C.

Agar colonies: At 56°C, circular, convex, smooth. Borders entire to irregular. Show curled structure, strands of chains. Brown by transmitted light.

Agar slant: Growth abundant, raised, glistening, contoured, bluish-green to bluish-white by transmitted light. After three weeks at 37°C, growth has a distinct reddish-brown color, butyrous, viscid.

Broth: Slightly turbid, no sediment. No surface growth, alkaline.

Litmus milk: Rennet coagulum, peptonization feeble, litmus reduced.

Potato: Amount of growth variable, brownish, spreading, glistening, slimy. Some strains do not grow.

Nitrites produced from nitrates, often with the production of nitrogen.

Starch is hydrolyzed.

Acid from glucose and salicin. Rhamnose, maltose, sucrose, raffinose, mannitol, sorbitol and inulin not fermented.

Acetylmethylcarbinol not produced.

Thermophilic, optimum temperature 60°C to 65°C. Growth at 73°C to 75°C but none at 80°C on agar slants.

Aerobic, facultative.

Good growth occurs in synthetic media containing potassium nitrate, sodium ammonium phosphate, aspartic acid, and sodium asparaginate, respectively, as only sources of nitrogen with glucose as source of carbon.

Source: Forty-eight cultures isolated from pasteurized milk at a single milk plant (Buffalo, N. Y.).

Habitat: Probably originally from soil and dust.

Thermobacillus digestans Feirer (Soil Sci., *23*, 1927, 50) seems to be closely related to the preceding. It is more strongly proteolytic, digesting milk completely in 7 days.

Source: Four strains isolated from soil.

21a. *Bacillus pepo* Shaw. (Jour. Inf. Dis., *43*, 1928, 473.) From *Cucurbita pepo*, the pumpkin.

From the brief original description, this organism seems to vary from *Bacillus kaustophilus* only in its distinctive viscid or slimy character.

Source: Two cultures isolated from swelled cans of pumpkin.

Habitat: Probably found in soil and dust.

22. **Bacillus thermoindifferens** Weinzirl. (Jour. Med. Research, *39*, 1919, 402.) From Greek *thermos*, hot and Latin *indifferens*, indifferent. Indifferent to or tolerant of heat.

Spores: Ellipsoidal, 0.5 by 0.8 micron, terminal.

Sporangia: Cylindrical, not swollen.

Rods: 0.7 by 2.0 to 4.5 microns, occurring singly and in short chains, with rounded ends. Motile. Gram-positive.

Gelatin stab: Growth filiform. Slow infundibuliform liquefaction.

Agar colonies: Circular, convex, smooth, entire, amorphous.

Agar slant: Growth flat, spreading, glistening, translucent, butyrous, contoured.

Broth: Turbid, abundant sediment. No surface growth.

Litmus milk: Alkaline. Litmus reduced.

Potato: No growth.

Indole not formed.

Nitrites not produced from nitrates.

Starch is hydrolyzed.

Acid from glucose. No acid from lactose, sucrose or mannitol.

Thermophilic, optimum temperature 55°C. Grows at 20° to 37°C.

Aerobic.

Source: Isolated from canned pumpkin.

Habitat: Probably found in soil and dust.

Thermobacillus reductans Feirer (Soil Sci., *23*, 1927, 51) is said to resemble *Bacillus thermoindifferens* except that nitrites are formed from nitrates and the minimum temperature is 40°C.

Source: Two strains isolated from soil.

Thermobacillus catenatus Feirer (Soil Sci., *23*, 1927, 53) may be related to this group. The description is very incomplete. Its distinctive feature is the production of indole.

Source: Two strains isolated from soil.

23. **Bacillus thermodiastaticus** Bergey et al. (Type 1, Bergey, Jour. Bact., *4*, 1919, 304; Bergey et al., Manual, 1st ed., 1923, 310.) From Greek *thermos*, hot and *diastatikos*, separative; M. L., enzymatic, diastatic; hence diastatic at high temperatures.

Spores: Of less diameter than that of the rods, ellipsoidal, central.

Sporangia: Cylindrical.

Rods: 0.5 to 0.7 by 2 to 3 microns, occurring in chains, with square ends. Motile with peritrichous flagella. Gram-positive.

Gelatin stab: Liquefaction.

Agar colonies: Grayish, spreading, with lobate to fimbriate borders.

Agar slant: Growth thin, limited, bluish-gray.

Broth: Turbid.

Litmus milk: Not coagulated, peptonized.

Potato: Growth slight, grayish.

Nitrites produced from nitrates.

Starch is hydrolyzed.

Thermophilic, optimum temperature 65°C. No growth at 50°C. Growth at 75°C.

Aerobic.

Source: Isolated from dust and contaminated milk.

Habitat: Probably widely distributed in soil and dust.

Thermobacillus diastasius Feirer (Soil Sci., *23*, 1927, 49) differs from *Bacillus thermodiastaticus* only in that nitrites are not formed from nitrates (Feirer).

Source: Two strains isolated from soil.

24. **Bacillus cylindricus** Blau. (Cent. f. Bakt., II Abt., *15*, 1905, 119.) From Greek *kylindrikos*, cylindrical.

Spores: Somewhat elongated, 0.7 to 1.1 by 1.8 to 2.5 microns, terminal. Remnants of sporangium adherent. Germination equatorial and oblique.

Sporangia: Cylindrical or only slightly swollen at end, not in chains.

Rods: On glucose agar at 60°C, 0.8 to 1.1 by 5.0 to 7.5 microns, occurring singly and in pairs. Motile with peritrichous flagella. Cells store glycogen. Gram-positive.

Gelatin stab: No liquefaction.

Glucose agar colonies: Grayish-white, entire to lobed to dentate. By transmitted light yellowish-brown centers with brownish-yellow borders. Finely fibrous structure.

Glucose agar slant: Growth thin, dull, grayish-white.

Litmus milk: Unchanged.

Potato: No growth.

Nitrites not produced from nitrates.

Starch not hydrolyzed.

Thermophilic, optimum temperature 60°C to 70°C.

Source: Isolated from moist field soil in Germany.

Habitat: Probably found in dust and soil.

Bacillus calidus Blau (Cent. f. Bakt., II Abt., *15*, 1905, 134) differs so little from the preceding species that it cannot be considered as distinct.

Source: Isolated from field soil in Germany (Blau). Dust, ground feeds, etc., about dairies and various dairy products (Prickett, N. Y. Agr. Exp. Sta. Tech. Bul. 147, 1928, 45).

25. **Bacillus robustus** Blau. (Cent. f. Bakt., II Abt., *15*, 1905, 126.) From Latin *robustus*, oaken, hard, firm.

Spores: Ellipsoidal, 1.0 by 1.6 to 2.2 microns, polar to medial. Remnants of sporangium not adherent. Germination prevailingly equatorial.

Sporangia: Ellipsoidal to cylindrical, not in chains.

Rods: 1.0 to 1.2 by 3 to 4 microns, occurring singly and in short chains. Motile. Gram-positive.

Glucose agar colonies: Circular, gray-white. By transmitted light brownish-yellow. Borders distinct, serrate to lobed, finely granular.

Glucose agar slant: Growth yellowish-white, translucent, becoming grayish-white, spreading, dull.

Potato: Growth yellowish-white, moist, glistening, smooth.

Nitrites not produced from nitrates.

Starch not hydrolyzed.

Thermophilic, optimum temperature 55°C to 60°C. Grows at 65°C.

Aerobic.

Source: Isolated from field soil near a forest in Germany.

Habitat: Probably found in soil and dust.

Thermobacillus restatus Feirer (Soil Sci., *23*, 1927, 51) is said to correspond in some respects with *Bacillus robustus*. Feirer states that it is not possible to definitely establish the identity because Blau failed to record the action of *Bacillus robustus* on nitrates and several other media and did not note the production of H_2S.

Source: Three strains isolated from soil.

25a. *Bacillus losanitchii* Bergey et al. (*Bacillus thermophilus losanitchii* Georgevitch, Cent. f. Bakt., II Abt., *27*, 1910, 164; Bergey et al., Manual, 1st ed., 1923, 313.) Named for Losanitch, near Vranje.

As far as can be determined from the meager description, this organism does not differ from *Bacillus robustus* except perhaps as to the maximum temperature allowing growth. Growth limits are 45°C to 78°C.

Source: Isolated from water of hot sulfur spring. Temperature of water 83°C.

Habitat: Probably in natural hot waters.

NOTE: Georgevitch (Arch. f. Hyg., *72*, 1910, 201) has described a thermophilic aerobic spore-forming sulfur bacillus from a hot sulfur spring at Vranje (Servia) under the name *Bacillus thermophilus vranjensis*. This does not grow on ordinary media unless sulfur compounds are added. It has a tuft of flagella at either end. Spores are ellipsoidal, terminal, distend the rod, and show polar germination.

Georgevitch (Cent. f. Bakt., II Abt., *27*, 1910, 150) describes a second thermophilic, motile, capsulated, ellipsoidal-spored rod from a chalybeate hot spring near Vranje under the name *Bacillus thermophilus jivoini*.

26. **Bacillus calidolactis** Hussong and Hammer. (Jour. Bact., *15*, 1928, 186.) From Latin *calidus*, warm, hot and *lac*, *lactis*, milk.

Gorini states (R. Ist. Lombardo Sci. e Lett. Rend., *76*, 1942, 3) that *Bacillus*

calidolactis is the same organism as *Bacillus lactis termophilus* (sic) Gorini (Giorn. d. R. Soc. Ital. d'Igiene, *16*, 1894, 16). From the descriptions this appears to be probable.

Spores: Ellipsoidal, of slightly greater diameter than the rods, terminal.

Sporangia: Slightly swollen, clavate.

Rods: 0.7 to 1.4 by 2.6 to 5.0 microns, occurring singly, in pairs and short chains. Non-motile. Gram-positive, some cells becoming Gram-negative with age.

Gelatin stab: No liquefaction.

No growth on plain nutrient agar.

Glucose agar colonies: Thin, white, opaque, filamentous.

Glucose agar slant: Growth abundant, echinate, dull, white.

Glucose agar stab: Growth abundant, beaded, gray.

Glucose broth: Turbid.

Litmus milk: Acid, coagulation. Litmus reduced.

Potato: No growth.

Nitrites produced from nitrates by some strains.

Acid from glucose, lactose, fructose, galactose and maltose. No acid from inulin, sucrose or glycerol.

Thermophilic, optimum temperature 55°C to 65°C. No growth at 37°C.

Aerobic, facultative.

Source: Isolated from normal pasteurized skim milk (Hussong and Hammer). Milk and milk powder (Prickett, N. Y. Agr. Exp. Sta. Tech. Bul. 147, 1928, 47).

Habitat: Probably in dairy products.

27. **Bacillus michaelisii** Prickett. (*Bacillus thermophilus aquatilis liquefaciens* Michaelis, Arch. f. Hyg., *36*, 1899, 285; Prickett, N. Y. Agr. Exp. Sta. Tech. Bul. 147, 1928, 45.) Named for Georg Michaelis of Berlin who first isolated the species.

Spores: Of greater diameter than the rods, terminal.

Sporangia: Swollen, clavate.

Rods: 0.6 to 0.8 by 2 to 4 microns. Motile. Gram-positive.

Gelatin stab: Liquefaction.

Agar colonies: Circular, raised, smooth, glistening.

Agar slant: Growth moderate, smooth, glistening.

Broth: Slight turbidity.

Milk: Not coagulated, alkaline.

Potato: Growth moist, glistening, yellowish, becoming brownish.

Nitrites with gas produced from nitrates.

Starch is hydrolyzed.

Acid from glucose and sucrose. No acid from rhamnose, maltose, lactose, glycerol, mannitol or inulin.

Thermophilic, optimum temperature 50°C to 60°C.

Aerobic, facultative.

Source: Isolated from fountain waters (Michaelis). From fodder, dust, dairy utensils (Prickett).

Habitat: Probably found in soil and dust.

27a. *Bacillus lobatus* Bergey et al. (Type 3, Bergey, Jour. Bact., *4*, 1919, 304; Bergey et al., Manual, 1st ed., 1923, 311.) From Greek *lobatos*, having the form of a lobe.

Judging from the meager description, there is no essential difference between this organism and the preceding.

Source: Isolated from dust, soil, and horse manure.

Habitat: Probably widely distributed in soil and decaying matter.

Bacillus nondiastaticus Bergey et al. (Type 2, Bergey, Jour. Bact., *4*, 1919, 304; Bergey et al., Manual, 1st ed., 1923, 310.) From Greek, no diastase.

The description of this organism is practically identical with *Bacillus lobatus*, the only difference noted being that this species hydrolyzes starch while *Bacillus nondiastaticus* does not.

Source: Isolated from dust and soil (Bergey). Ground grains, raw and pasteurized milk (Prickett, N. Y. Agr. Exp. Sta. Tech. Bul. 147, 1928, 47).

Thermobacillus vulgaris Feirer (Soil Sci., *23*, 1927, 50) liquefies gelatin, does

not reduce nitrates to nitrites nor alter litmus milk. According to Feirer it is otherwise similar to *Bacillus nondiastaticus*.

Source: Two strains isolated from soil.

27b. *Bacillus thermononliquefaciens* Bergey et al. (Type 4, Bergey, Jour. Bact., *4*, 1919, 304; Bergey et al., Manual, 1st ed., 1923, 312.) From Greek *thermos*, hot; and Latin *non*, not and *liquefaciens*, making liquid. Probably intended to mean thermophilic and non-gelatin-liquefying.

Aside from the non-liquefaction of gelatin, there seems to be no difference in the description of this organism and the two immediately preceding.

Source: Isolated from dust, soil, and horse manure.

Habitat: Probably found in soil and decaying matter.

28. **Bacillus thermotranslucens** Bergey et al. (Type 5, var. b, Bergey, Jour. Bact., *4*, 1919, 304; Bergey et al., Manual, 1st ed., 1923, 312.) From Greek *thermos*, hot and Latin *translucens*, translucent. Probably intended to mean thermophilic and translucent.

Spores: Of larger diameter than the rods, terminal.

Sporangia: Terminally swollen, clavate, not in chains.

Rods: 0.3 to 0.4 by 1.0 to 1.5 microns, occurring singly. Motile with peritrichous flagella. Gram-positive.

Gelatin stab: No liquefaction.

Agar colonies: Thin, transparent, spreading widely.

Agar slant: Growth thin, spreading, veil-like.

Broth: Turbid.

Litmus milk: Not coagulated, slightly acid.

Potato: No growth.

Nitrites not produced from nitrates.

Starch slightly hydrolyzed.

Thermophilic, optimum temperature 60°C. Slight growth at 37°C. No growth at 70°C.

Aerobic.

Source: Isolated from guinea pig feces, dust and from cheese.

Habitat: Probably found in soil and decaying matter.

Thermobacillus linearius Feirer (Soil Sci., *23*, 1927, 53) is said to be similar in some respects to the preceding. Feirer states that formation of acid from several sugars is the distinctive feature of this species, a character not mentioned by Bergey.

Source: Five strains isolated from soil.

28a. *Bacillus stearothermophilus* Donk. (Jour. Bact., *5*, 1920, 373.) From Greek *stéār*, tallow and *thermophilos*, heat-loving. Intended meaning obscure.

From the descriptions, the vegetative rods of this organism seem to be slightly larger than the preceding, otherwise no difference is noted.

Source: Isolated from samples of spoiled canned corn and string beans.

Habitat: Probably found in soil and dust.

28b. *Bacillus aerothermophilus* Weinzirl. (Jour. Med. Research, *39*, 1919, 403.) From Greek *aeros*, air and *thermophilus*, heat-loving. Probably intended to mean aerobic and thermophilic.

There is nothing in the original account of this organism which is at variance with that of the preceding.

Source: Isolated from canned string beans (Weinzirl). From milk, water, hay, dust, beef extract, and agar (Prickett, N. Y. Agr. Exp. Station Tech. Bull. 147, 1928, 46).

Habitat: Probably found in soil and dust.

Thermobacillus alcalinus Feirer (Soil Sci., *23*, 1927, 52) is said to differ from the preceding in that it does not change litmus milk.

Source: Four strains isolated from soil.

Thermobacillus ruber Feirer (Soil Sci., *23*, 1927, 52) apparently is closely related to this group. Its distinguishing character is the production of a pink pigment

in meat, brain, and blood serum, no color on other media.

Source: Isolated from soil.

29. **Bacillus thermocellulolyticus** Coolhaas. (Cent. f. Bakt., II Abt., *76*, 1928, 43.) From Greek *thermos*, hot; and Latin *cellula*, a small room; M. L., cellulose and Greek *lytikos*, dissolving. Probably intended to mean thermophilic and cellulose-digesting.

Spores: Ellipsoidal, 0.8 by 1.5 microns, terminal.

Sporangia: Terminally swollen, clavate.

Rods: 0.3 by 3.5 to 6 microns, occurring singly and in pairs. No reserve material. Non-motile. Gram-positive.

Gelatin stab: No liquefaction.

Glucose agar colonies: Small, glistening, translucent.

Cellulose agar colonies: Circular, borders undulate to lobate.

Broth: Slight growth, no surface growth or sediment.

Milk: No growth.

Nitrites not produced from nitrates.

Starch is hydrolyzed.

No acid from carbohydrates.

Cellulose hydrolyzed.

Thermophilic, optimum temperature 50°C to 55°C. Maximum 60°C to 65°C. Minimum 35°C to 37°C.

Aerobic, facultative.

Source: Isolated from sewage.

Habitat: Probably found in decaying matter.

30. **Bacillus thermoalimentophilus** Weinzirl. (Jour. Med. Research, *39*, 1919, 404.) From Greek *thermos*, hot; Latin *alimentum*, food; and Greek *philos*, loving. Loving hot food.

Spores: Ellipsoidal, 0.8 by 1.0 micron, terminal.

Sporangia: Swollen, clavate, not in chains.

Rods: 0.6 by 3.0 microns, occurring singly, with rounded ends. Motile, flagella not stated. Gram-positive.

Gelatin stab: No growth at 20°C.

Agar colonies: Circular, raised, smooth, amorphous, entire.

Agar slant: Growth spreading to effuse, smooth, glistening, butyrous.

Broth: Turbid, surface ring.

Litmus milk: Unchanged.

Potato: No growth.

Nitrites with gas produced from nitrates.

Starch not hydrolyzed.

Neither acid nor gas from glucose, lactose, sucrose or mannitol.

Thermophilic, optimum temperature 55°C. No growth at 20°C. Growth at 37°C.

Aerobic.

Source: Isolated from canned blueberries (Weinzirl). Pasteurized milk and filter cloth (Prickett, N. Y. Agr. Exp. Sta. Tech. Bul. 147, 1928, 46).

Habitat: Probably found in soil and dust.

Thermobacillus violaceus Feirer (Soil Sci., *23*, 1927, 52) corresponds in some respects with the preceding. Feirer also states that his cultures did not reduce nitrates to nitrites and produced acid on glucose and sucrose.

Source: Four strains isolated from soil.

31. **Bacillus thermoliquefaciens** Bergey et al. (Type 5, var. a, Bergey, Jour. Bact., *4*, 1919, 304; Bergey et al., Manual, 1st ed., 1923, 313.) From Greek *thermos*, hot, and Latin *liquefaciens*, liquefying. Probably intended to mean thermophilic and gelatin-liquefying.

Spores: Ellipsoidal, polar, of greater diameter than the rods.

Sporangia: Terminally swollen, clavate.

Rods: 0.2 to 0.4 by 2 to 3 microns, occurring singly, with rounded ends. Motile with peritrichous flagella. Gram-positive.

Gelatin stab: Liquefaction.

Agar colonies: Moderately dense, lobate.

Agar slant: Growth dense, grayish, lobate to fimbriate margins.

Litmus milk: Coagulated, acid. Litmus reduced.

Potato: No growth.

Nitrites and ammonia produced from nitrates.

Starch not hydrolyzed.

Thermophilic, optimum temperature 60°C. Slight growth at 37°C. No growth at 70°C.

Aerobic.

Source: Isolated from dust, guinea pig feces and horse manure (Bergey). Water and milk (Prickett, N. Y. Agr. Exp. Sta. Tech. Bul. 147, 1928, 47).

Habitat: Probably originally from soil nd dust.

32. **Bacillus tostus** Blau. (Cent. f. Bakt., II Abt., *15*, 1905, 130.) From Latin *tostus*, parched, dried.

Spores: Ellipsoidal, 0.8 to 1.6 by 1.5 to 2.2 microns. Germination prevailingly polar.

Sporangia: Terminally swollen, clavate, not in chains.

Rods: 1.2 by 4.5 to 5.0 microns, occurring in pairs and in short chains. Cells store glycogen. Motile with peritrichous flagella.

Agar colonies: Small, circular, dense. By transmitted light bright yellow to yellowish-brown. Borders sharp, entire to lobate. Older colonies porcelain-like.

Agar slant: Growth thin, grayish-white, spreading, smooth, glistening.

Potato: No growth.

Nitrites not produced from nitrates.

Starch is hydrolyzed.

Ammonia is produced.

Thermophilic, optimum temperature 60°C to 70°C.

Aerobic.

Source: Two cultures isolated from soil in Germany.

Habitat: Probably found in soil and dust.

33. **Bacillus viridulus** (Migula) Bergey et al. (*Bacillus thermophilus II* Rabinowitsch, Ztschr. f. Hyg., *20*, 1895, 154; *Bacterium viridulum* Migula, Syst. der Bakt., *2*, 1900, 343; *Bacterium thermophilum II* Chester, Manual, 1901, 186; ***Bacillus thermophilus*** Bergey et al., Manual, 1st ed., 1923, 315; Bergey et al., Manual, 4th ed., 1934, 464; not *Bacillus thermophilus* Miquel, Ann. d. Microg., *1*, 1888, 6; not *Bacillus thermophilus* Chester, Man. Determ. Bact., 1901, 265.) From Latin, dim. adj. *viridis*, green, somewhat green.

Spores: Spherical, central.

Sporangia: Cylindrical, not swollen.

Rods: Rather large, slightly bent, occurring singly and in pairs. Nonmotile. Gram-positive.

Agar colonies: Irregular, spreading, granular, greenish.

Broth: Alkaline.

Potato: Growth grayish-yellow; margin undulate.

Nitrites not produced from nitrates.

Starch is hydrolyzed.

Thermophilic, grows at 60°C to 70°C. Optimum temperature 62°C. Grows at 33°C.

Aerobic, facultative.

Source: Isolated from soil, snow, feces, corn grains.

Habitat: Probably found in soil and dust.

Appendix: The following additional aerobic spore-forming bacteria are found in the literature. Because of insufficient data it has not been possible to classify them. Some of these may be synonyms of well-known species, some may be varieties, whereas others may actually be separate species.

Aromabacillus weigmanni Omeliansky. (Isolated by Weigmann, 1890; Omeliansky, Jour. Bact., *8*, 1923, 398.) From milk.

Bacillus abysseus ZoBell and Upham. (Bull. Scripps Inst. of Oceanography, Univ. Calif., *5*, 1944, 273.) Subterminal spores. From marine mud.

Bacillus acidifaciens Patrick and Werkman. (Iowa State Coll. Jour. Sci., *7*, 1933, 413.) One of a group characterized by the fermentation of xylan. A single culture isolated from decayed maple wood.

Bacillus acidificans presamigenes casei

Gorini. (Rend. R. Accad. dei Lincei, *8*, 1928, 598.) From manure, fodder and milk. Regarded by Gorini (personal communication, 1925) as identical with *Bacillus circulans* Jordan.

Bacillus acido-proteolyticus casei Gorini. (Le Lait, *9*, 1912, 98.) From Parmesan and Emmenthal cheese. Regarded by Gorini (personal communication, 1925) as equivalent to one of the species of *Tyrothrix* of Duclaux.

Bacillus adametzi Trevisan. (Brauner Wasserbacillus, Adametz and Wichmann, Mittheil. d. oesterr. Versuchsstat. f. Brauerei u. Mälzerei, Wien, Heft 1, 1888, 51; Trevisan, I generi e le specie delle Batteriacee, 1889, 19; not *Bacillus adametzii* Migula, Syst. d. Bakt., *2*, 1900, 686; *Bacillus brunneus* Eisenberg, Bakt. Diag., 3 Aufl., 1891, 142; *Bacterium brunneum* Migula, *ibid.*, 331; not *Bacterium brunneneum* Schroeter, in Cohn, Beitr. z. Biol. d. Pflanz., *1*, Heft 2, 1882, 125.) From water.

Bacillus adhaerens Laubach. (Jour. Bact., *1*, 1916, 503.) One culture isolated from dust.

Bacillus aegyptiacus Werner. (Cent. f. Bakt., II Abt., *87*, 1933, 459.) Good growth on Ca n-butyrate agar. One culture isolated from Egyptian soil.

Bacillus aerifaciens Steinhaus. (Jour. Bact., *42*, 1941, 782.) Author states that it probably belongs to the *Aerobacillus* group. From triturated specimens of the white cabbage butterfly (*Pieris rapae*).

Bacillus aerobius von Wahl. (Cent. f. Bakt., II Abt., *16*, 1906, 496.) Reported to resemble *Bacillus mesentericus fuscus*. From canned peas.

Bacillus aerophilus Flügge. (Flügge, Die Mikroorganismen, 2 Aufl., 1886, 321; *Bacterium aerophilum* Chester, Man. Determ. Bact., 1901, 191.) From dust.

Bacillus afanassieffi Trevisan. (*Bacillus tussis convulsivae* Afanassief, St. Petersburg. med. Wochnschr., 1887, No. 38–42; not *Bacillus tussis convulsivae* Lehmann and Neumann, Bakt. Diag., 4 Aufl., *2*, 1907, 269; Trevisan, I generi e le specie delle Batteriacee, 1889, 13; *Bacillus pertussis* Migula, Syst. d. Bakt., *2*, 1900, 754.) From mucus and pus.

Bacillus agilis Tschistowitsch. (Tschistowitsch, Berl. klin. Wochnschr., 1892, 512; not *Bacillus agilis* Trevisan, I generi e le specie delle Batteriacee, 1889, 14; not *Bacillus agilis* Chester, Man. Determ. Bact., 1901, 226; not *Bacillus agilis* Mattes, Sitzungsber. d. Gesellsch. z. Beforderung d. gesam. Naturw. z. Marburg, *62*, 1927, 406; not *Bacillus agilis* Hauduroy et al., Dict. d. Bact. Path., Paris, 1937, 33.) From pus.

Bacillus agilis Hauduroy et al. (*Bacillus agilis larvae* Toumanoff, Bull. Soc. Cent. de Méd. Vétér., *80*, 1927, 367; Hauduroy, Ehringer, Urbain, Guillot and Magrou, Dictionnaire de Bactéries Pathogènes, Paris, 1937, 33.) Found in foulbrood of bees.

Bacillus agrestis Werner. (Cent. f. Bakt., II Abt., *87*, 1933, 468; not *Bacillus agrestis* de Rossi, Microbiol. agraria e technica, Torino, 1927, 828.) One of a group of species described as being able to grow on a Ca n-butyrate agar. Three cultures were isolated from German and Italian soils.

Bacillus agri Laubach and Rice. (Jour. Bact., *1*, 1916, 516.) Isolated twice from soil in Baltimore.

Bacillus agrophilus Stührk. (Cent. f. Bakt., II Abt., *93*, 1935, 189.) Only moderate growth on Ca n-butyrate agar. One culture isolated from soil from Cuba.

Bacillus agrotidis typhoides Pospelov. (Rept. Bur. Appl. Ent., Russian, *3*, 1927, 8.) Found in diseased larvae of the moth, *Euxoa* (*Agrotis*) *segetum*.

Bacillus (*Streptobacter*) *albuminis* Schroeter. (Bacillus aus Faeces V, Bienstock, Ztschr. f. klin. Med., *8*, Heft 1, 1884, 1; Schroeter, in Cohn, Kryptog. Flora v. Schlesien, *3*, 1, 1886, 162; *Bacillus putrificus coli* Flügge, Die Mikroorganismen, 2 Aufl., 1886, 303; *Bacillus diaphthirus* Trevisan, I generi e le specie delle Batteriacee, 1889, 15.) From feces.

Bacillus albus (Sack) Bergey et al. (*Cellulomonas albus* Sack, Cent. f. Bakt., II Abt., *62*, 1924, 79; Bergey et al., Man-

ual, 3rd ed., 1930, 398; not *Bacillus albus* Trevisan, I generi e le specie delle Batteriacee, 1889, 14; not *Bacillus albus* Copeland, Report Filtration Comm., Pittsburgh, 1899, 344.) Cellulose is hydrolyzed. From soil in Germany.

Bacillus alcalophilus Vedder. (Ned. Tijdschr. v. Hyg. Microbiol. en Serolog., *1*, 1934, 141.) Grows only in and on highly alkaline culture media. Sixteen strains isolated from the feces of healthy animals.

Bacillus alopecuri Nogtev. (Botanicheskii Zhurnal, U.S.S.R., *23*, 1938, 149.) Causes nodule formation on fox grass (*Alopecurus pratensis*).

Bacillus alpha Dyar. (Ann. N. Y. Acad. Sci., *8*, 1895, 366.) From the air.

Bacillus alpinus Werner. (Cent. f. Bakt., II Abt., *87*, 1933, 465.) Good growth on calcium salts of formic, acetic, propionic and butyric acids. One culture isolated from soil from Austria.

Bacillus alveolaris Ksenjoposky. (Review of pests of Volhymia, Volhymia Ent. Bur., Zemstvo of Volhymia, Zitomir, 1916, 24 pp.) From diseased bees (*Apis mellifera*).

Bacillus amarus Hammer. (Iowa Agr. Exp. Station Res. Bull. 52, 1919, 198.) From evaporated milk.

Bacillus aminovorans den Dooren de Jong. (Cent. f. Bakt., II Abt., *71*, 1927, 215.) From soil.

Bacillus amyloaerobius Crimi. (Abst. in Cent. f. Bakt., II Abt., *61*, 1924, 63.) From potato rot.

Bacillus amylolyticus Kellerman and McBeth. (Cent. f. Bakt., II Abt., *34*, 1912, 490.) Decomposes cellulose. One culture isolated from manure.

Bacillus annuliformis Migula. (Fadenähnlicher Bacillus, Maschek, Bakt. Untersuch. d. Leitmeritzer Trinkwässer, Leitmeritz, 1887; Migula, Syst. d. Bakt, *2*, 1900, 783.) From water.

Bacillus anthracis similis McFarland. (Cent. f. Bakt., I Abt., *24*, 1898, 556.) From dust.

Bacillus apicum Canestrini. (Atti Soc. Ven. Trent. Sci. Nat., 91; according to Kruse, in Flügge, Die Mikroorganismen, 3 Aufl., *2*, 1896, 233.) From diseased bees and their larvae.

Bacillus aporrhoeus Fuller and Norman. (Jour. Bact., *46*, 1943, 277.) From soil. Decomposes cellulose.

Bacillus arachnoideus Migula. (Bacillus No. III, Flügge, Ztschr. f. Hyg., *17*, 1894, 294; *Bacillus lactis* No. III, Kruse, in Flügge, Die Mikroorganismen, 3 Aufl., *2*, 1896, 208; Migula, Syst. d. Bakt., *2*, 1900, 583; *Bacterium lacteum* Migula, *ibid.*, 321.) From milk.

Bacillus arenarius Stührk. (Cent. f. Bakt., II Abt., *93*, 1935, 187.) Good growth on Ca n-butyrate agar. One strain isolated from Cuban soil.

Bacillus aridus Migula. (Bacillus No. 8, Pansini, Arch. f. path. Anat., *122*, 1890, 444; Migula, Syst. d. Bakt., *2*, 1900, 559.) From sputum.

Bacillus arlongii (sic) DeToni and Trevisan. (Bacillus de la septicèmie gangrèneuse, Arloing and Chauveau, see Crookshank, Man. of Bact., 3rd ed., 1890, 305; DeToni and Trevisan, in Saccardo, Sylloge Fungorúm, *8*, 1889, 950.) From wounds in gangrenous septicaemia.

Bacillus asiaticus Sakharoff. (Sakharoff, Ann. Inst. Past., *8*, 1893, 550; not *Bacillus asiaticus* Castellani, Cent. f. Bakt., I Abt., Orig., *65*, 1912, 262.) From feces in a case of cholera.

Bacillus asteris Verona. (Riv. Pat. Veg., *25*, 1935, 15.) Pathogenic for China aster (*Aster chinensis*).

Bacillus asthenogenes Bernard. (Ann. Inst. Past., *35*, 1921, 459.) Grows aerobically as well as anaerobically. Under anaerobic conditions it is said to play a role in gastric derangement and infection commonly confused with beriberi. Author reports that it is very similar to *Bacillus megatherium*.

Bacillus aterrimus tschitensis Klimenko. (Cent. f. Bakt., II Abt., *20*, 1908, 1.) Reported to be like the black potato bacillus except that it forms a black pigment on gelatin and the potato is brown instead of black. From air.

Bacillus aurantius (Sack) Bergey et al.

(*Cellulomonas aurantius* Sack, Cent. f. Bakt., II Abt., *62*, 1924, 78; Bergey et al., Manual, 3rd ed., 1930, 421; not *Bacillus aurantius* Trevisan, I generi e le specie delle Batteriacee, 1889, 19.) From soil.

Bacillus badius Batchelor. (Jour. Bact., *4*, 1919, 25.) From the intestinal tract of children.

Bacillus balcanus Bartels. (Cent. f. Bakt., II Abt., *103*, 1940, 25.) Growth on media containing M/50 phenol. Eight strains isolated from soil.

Bacillus barbitistes Statelov. (Mitt. bulg. ent. Gesells., 7, 1932, 56–61.) From diseased tettigonids (*Isophya* (*Barbitistes*) *amplipennis*).

Bacillus batatae Otani. (Trans. Tottori Soc. Agric. Sci., Japan, *6*, 1939, 222.) From rotten sweet potatoes (*Ipomaea batatas*).

Bacillus bellus Heigener. (Cent. f. Bakt., II Abt., *93*, 1935, 96.) Probably a strain of *Bacillus brevis*. One culture isolated from garden soil of Germany.

Bacillus bernensis Lehmann and Neumann. (Aromabacillus, Burri, Cent. f. Bakt., II Abt., *3*, 1897, 609; Lehmann and Neumann, Bakt. Diag., 2 Aufl., *2*, 1899, 304; *Bacillus odoratus* Migula, Syst. d. Bakt., *2*, 1900, 686; *Bacterium odoratum* Omeliansky, Jour. Bact., *8*, 1923, 394.) From Emmenthal cheese. Reported as producing the aroma of this cheese.

Bacillus beta Dyar. (Ann. N. Y. Acad. Sci., *8*, 1895, 366.) From dust.

Bacillus betainovorans Heigener. (Cent. f. Bakt., II Abt., *93*, 1935, 94.) Good growth on betaine and valine agar. One culture isolated from soil from Mantua.

Bacillus betanigrificans Cameron, Esty and Williams. (Food Research, *1*, 1936, 75.) From blackened canned beets where juice contains an abnormally high amount of iron.

Bacillus biacutum Soriano. (Revista del Inst. Bacteriol., Univ. Buenos Aires, *6*, 1935, 564.) From soil.

Bacillus bombycis Macchiati. (Des vibrions, Pasteur, Études sur la maladie des vers à soie, La Flacherie, Chapitre II, Paris, 1870; Macchiati, Stazioni sperimentali Agrarie Italiane, *20*, 1891, 121; not *Bacillus bombycis* Chatton, Compt. rend. Acad. Sci., Paris, *156*, 1913, 1708; *Bacillus megaterium bombycis* Sawamura, Tokyo Imp. Coll. Agric. Bull., *6*, 1905, 375.) Pasteur originally isolated this large bacillus from the intestine of silkworms (*Bombyx mori*) suffering from wilt disease. Regarded by Sawamura as a variety of *Bacillus megatherium*.

Bacillus bombycis non-liquefaciens Paillot. (Ann. Épiphyt., *8*, 1922, 131; L'infection chez les insectes, 1933, 288.) Larvae of the gypsy moth (*Lymantria dispar*) are immune to this bacillus.

Bacillus bombycoides Paillot. (Compt. rend. Acad. Agr. France, *28*, 1942, 158.) Causes lesions because of a bacterial toxin. From infected silkworms.

Bacillus bombysepticus Hartman. (Lingnan Sci. Jour., *10*, 1931, 280.) Causes a disease of the silkworm (*Bombyx mori*).

Bacillus borborokoites ZoBell and Upham. (Bull. Scripps Inst. of Oceanography, Univ. Calif., *5*, 1944, 274.) Central spores. From marine bottom deposits.

Bacillus borstelensis Stührk. (Cent. f. Bakt., II Abt., *93*, 1935, 179.) Grows well on Ca n-butyrate agar. Resembles *Bacillus rufescens* of the same group except that it does not show the typical brown coloration of media. Two strains isolated from soils in Germany.

Bacillus bredemannii Chester. (*Bacillus adhaerens* Stührk, Cent. f. Bakt., II Abt., *93*, 1935, 183; not *Bacillus adhaerens* Laubach, Jour. Bact., *1*, 1916, 503; Chester, in Manual, 5th ed., 1939, 675.) Weak growth on Ca n-butyrate agar. One strain isolated from Cuban soil.

Bacillus bronchitidis Migula. (Bacillus der putriden Bronchitis, Lumnitzer, Cent. f. Bakt., *3*, 1888, 621; *Bacillus bronchitidis putridae* Lumnitzer, Wien. med. Presse, 1888, 666; Migula, Syst. d. Bakt., *2*, 1900, 641; *Bacterium lumnitzeri* Chester, Man. Determ. Bact., 1901, 120.)

From sputum in cases of putrid bronchitis.

Bacillus bruneus Migula. (Maschek, Bakt. Untersuch. d. Leitmeritzer Trinkwasser, 1887; Migula, Syst. d. Bakt., *2*, 1900, 835; not *Bacillus brunneus* Eisenberg, Bakt. Diag., 3 Aufl., 1891, 142.) From water.

Bacillus brunneus Eisenberg. (Brauner Wasserbacillus, Adametz and Wichmann, Die Bakt. d. Nutz- u. Trinkwässer, Mitth. Oesterreich. Versuchssta. f. Brauerei u. Mälzerei, Wien, Heft 1, 1888, 51; Eisenberg, Bakt. Diag., 3 Aufl., 1891, 142; not *Bacillus brunneus* Schroeter, in Cohn, Kryptog. Flora v. Schlesien, *3*, 1, 1886, 158; *Bacterium brunneum* Migula, Syst. d. Bakt., *2*, 1900, 331.) From water. Non-motile.

Bacillus butlerovii Serbinow. (Věst. Russ. obšč. pčelovod. (Messager de la Soc. russe d'Apiculture), No. 3 and No. 11, 1912; see Rev. Appl. Entomol., Ser. A, *1*, 1913, 94 and 441.) From black brood of bees.

Bacillus bütschlii Schaudinn. (Arch. f. Protistenkunde, *1*, 1902, 306.) Characterized by its large size (3.0 to 6.0 by 24.0 to 80.0 microns) and granular protoplasm. From the intestine of a cockroach (*Blatta* (*Periplaneta*) *orientalis*).

Bacillus butyricus Hueppe. (Hueppe, Mitteil. kaiserl. Gesundheitsamte, *2*, 1884, 309; not *Bacillus butyricus* Macé, Traité de Bact., 1st ed., 1888; not *Bacillus butyricus* Botkin, Ztschr. f. Hyg., *11*, 1892, 421; *Clostridium hueppei* Trevisan, I generi e le specie delle Batteriacee, 1889, 22; *Bacillus pseudobutyricus* Kruse, in Flügge, Die Mikroorganismen, 3 Aufl., *2*, 1896, 207; *Bacillus hueppei* Chester, Man. Determ. Bact., 1901, 276.)

Bacillus calfactor Miehe. (Arb. der deutsch. Landw. Gesel., Berlin, Heft 3, 1905, 76; Die Selbsterhitzung des Heues, Jena, 1907, 49.) Thought to be the most important thermogenic microorganism in the fermentation of hay. From heating hay.

Bacillus canaliculatus Wilhelmy. (Arb. bakt. Inst. Karlsruhe, *3*, 1903, 20.) From meat extract.

Bacillus canceris Migula. (Syst. d. Bakt., *2*, 1900, 625.) From a case of stomach cancer.

Bacillus caniperda Migula. (Ovalbacillus der Hundestaupe, Galli-Valerio, Cent. f. Bakt., I Abt., *19*, 1896, 694; Migula, Syst. d. Bakt., *2*, 1900, 764; *Bacterium canis* Chester, Man. Determ. Bact., 1901, 198.) From nasal mucus and urine of dogs.

Bacillus capillaceus Wright. (Mem. Nat. Acad. Sci., *7*, 1895, 456.) From water.

Bacillus capsici Pavarino and Turconi. (Atti Istit. Bot. R. Univ. Pavia, *15*, 1918, 207.) Causes leaf wilt of pepper (*Capsicum annuum*). May be identical with disease caused by *Pseudomonas vesicatoria* (Stapp, in Sorauer, Handbuch der Pflanzen-Krankheiten, *2*, 5 Aufl., 1928, 262).

Bacillus carniphilus Wilhelmy. (Arb. bakt. Inst. Karlsruhe, *3*, 1903, 19.) From meat extract.

Bacillus carnosus Zimmermann. (Tils, Bakt. Untersuch. d. Freiburg. Leitungswässer, Leipzig, 1890, No. 57; Zimmermann, Bakt. unserer Trink- u. Nutzwässer, Chemnitz, II Reihe, 1894, 4.) From water.

Bacillus catenulatus Bartels. (Cent. f. Bakt., II Abt., *103*, 1940, 27.) Growth on media containing M/100 phenol. Four strains isolated from soil.

Bacillus cepae Bassalik and Edelstein-Kosowa. (Acta Soc. Bot. Polon., *10*, 1933, 519.) From diseased onions (*Allium cepa*).

Bacillus cerealium Gentner. (Cent. f. Bakt., II Abt., *50*, 1920, 428; *Pseudomonas cerealia* Stapp, in Sorauer, Handbuch der Pflanzen-Krankheiten, *2*, 1928, 22; *Bacterium cerealinum* Elliott, Manual Bacterial Plant Pathogens, 1930, 111.) Pathogenic for barley (*Hordeum vulgare*), rye (*Secale cereale*) and wheat (*Triticum sp.*).

Bacillus cinctus Ravenel. (Mem. Nat. Acad. Sci., *8*, 1896, 30.) From soil.

Bacillus cirroflagellosus ZoBell and Upham. (Bull. Scripps Inst. of Oceanography, Univ. Calif., *5*, 1944, 266.) Central spores. Found in marine mud.

Bacillus cladoi Trevisan. (Bacille pedunculé, Clado, Bull. Soc. Anat. Paris, 1887, 339; Trevisan, I generi e le specie delle Batteriacee, 1889, 14; *Bacillus pendunculatus* (sic) Eisenberg, Bakt. Diag., 3 Aufl., 1891, 340; *Bacillus septicus vesicae* Sternberg, Man. of Bact., 1893, 475.) From urine in a case of cystitis.

Bacillus closteroides Gray and Thornton. (Cent. f. Bakt., II Abt., *73*, 1928, 93.) Decomposes phenol. Probably identical with or a variety of *Bacillus circulans*. Sixteen strains isolated from Rothamsted soils.

Bacillus coccineus Pansini. (Pansini, Arch. f. path. Anat., *122*, 1890, 437; not *Bacillus coccineus* Catiano, in Cohn, Beitr. z. Biol. d. Pflanzen, 7, 1896, 339.) From sputum. Red pigment.

Bacillus colorans Libermann. (Jour. of Microbiol., Ukraine, *5*, 1938, 73; abst. in Cent. f. Bakt., II Abt., *101*, 1940, 81.) From fruit conserves containing 10 to 20 per cent sugar.

Bacillus comesii Rossi. (Ann. d. Scuola d. Agricult. in Portici, 1903; Arch. di Farmacologia sperim., *3*, 1904, fasc. 10.) Similar to *Bacillus mesentericus*. Said to have the ability to dissolve plant particles.

Bacillus concoctans Patrick and Werkman. (Iowa State Coll. Jour. Sci., 7, 1933, 415.) Ferments xylan. One culture isolated from soil.

Bacillus conjunctivitidis subtiliformis Michalski. (Cent. f. Bakt., I Abt., Orig., *36*, 1904, 212.) From more than 50 cases of acute conjunctivitis. Similar to *Bacillus subtilis*.

Bacillus consolidus Stührk. (Cent. f. Bakt., II Abt., *93*, 1935, 191.) Good growth on Ca n-butyrate agar. One strain isolated from Cuban soil.

Bacillus contextus Migula. (*Bacillus D*, Peters, Botan. Zeitung, *47*, 1889; Migula, Syst. d. Bakt., *2*, 1900, 522.) From leaven.

Bacillus corrugatus Migula. (*Bacillus mesentericus vulgatus* Flügge, Die Mikroorganismen, 2 Aufl., 1886, 322; Bacillus No. II, Flügge, Ztschr. f. Hyg., *17*, 1894, 294; *Bacillus lactis* No. II, Kruse, in Flügge, Die Mikroorganismen, 3 Aufl., *2*, 1896, 208; Migula, Syst. d. Bakt., *2*, 1900, 583.) From milk.

Bacillus corruscans Schroeter. (In Cohn, Kryptog. Flora v. Schlesien, *3*, 1, 1886, 158.) From cooked potato.

Bacillus costatus Lloyd. (Jour. Bact., *21*, 1931, 94.) From sea water off Scotland. Nitrates and nitrites reduced to nitrogen.

Bacillus crinatus Chester. (Bacillus No. 5, Pansini, Arch. f. path. Anat., *122*, 1890, 441; Chester, Man. Determ. Bact., 1901, 281.) From sputum.

Bacillus crinitus Wright. (Wright, Mem. Nat. Acad. Sci., 7, 1895, 453; *Bacterium crinatum* (sic) Chester, Man. Determ. Bact., 1901, 192.) From river water.

Bacillus crystalloides Dyar. (Dyar, Ann. N. Y. Acad. Sci., *8*, 1895, 371; *Bacterium crystaloides* (sic) Chester, Man. Determ. Bact., 1901, 191.) From the air.

Bacillus cubensis Stührk. (Cent. f. Bakt., II Abt., *93*, 1935, 192.) Good growth on Ca n-butyrate agar. Two cultures isolated from soils from Cuba.

Bacillus cystiformis Trevisan. (Bacille cystiforme, Clado, Bull. Soc. Anat. Paris, 1887, 339; Trevisan, I generi e le specie delle Batteriacee, 1889, 14.) From urine in a case of cystitis.

Bacillus cytaseus McBeth and Scales. (U. S. Dept. Agr., Bur. Plant Industry, Bull. 266, 1913, 39; *Bacterium cytaseum* Holland, Jour. Bact., *5*, 1920, 218.) Requires cellulose for best growth. From decomposing materials and soil.

Bacillus cytaseus var. *zonalis* Kellerman et al. (Cent. f. Bakt., II Abt., *39*, 1913, 511.) From soil from Utah. While no spores were observed, this organism was like *Bacillus cytaseus* except that colonies on cellulose agar showed con-

centric opaque or semi-opaque and transparent zones.

Bacillus danteci Kruse. (Bacille rouge de Terre-Neuve, Le Dantec, Ann. Inst. Past., *5*, 1891, 662; Kruse, in Flügge, Die Mikroorganismen, 3 Aufl., *2*, 1896, 270.) From reddened salt cod fish.

Bacillus daucarum von Wahl. (Cent. f. Bakt., II Abt., *16*, 1906, 494.) Apparently a strain of *Bacillus subtilis*. From canned carrots.

Bacillus demmei Trevisan. (Bacillus der Erythema nodosum, Demme, Fortschr. d. Med., *6*, 1888, 257; Trevisan, I generi e le specie delle Batteriacee, 1889, 14; *Bacillus erythematis* Kruse, in Flügge, Die Mikroorganismen, 3 Aufl., *2*, 1896, 426; *Bacillus erythematis maligni* Kruse, *ibid.*, 479; *Bacterium erythematis* Migula, Syst. d. Bakt., *2*, 1900, 346.) From erythema nodosum (skin).

Bacillus dendroides Holzmüller. (Cent. f. Bakt., II Abt., *23*, 1909, 331.) From frog feces. Closely related to *Bacillus mycoides*.

Bacillus dendroides Thornton. (Thornton, Ann. Appl. Biol., *9*, 1922, 247; not *Bacillus dendroides* Holzmüller, *loc. cit.*) Common in Rothamsted soil. Said to belong to the *Bacillus subtilis* group.

Bacillus dentatus Heigener. (Cent. f. Bakt., II Abt., *93*, 1935, 106.) Good growth on valine agar. Two cultures isolated from soil of Jugoslavia and North Carolina.

Bacillus destruens von Wahl. (Cent. f. Bakt., II Abt., *16*, 1906, 502.) From boiled asparagus.

Bacillus detrudens Wright. (Mem. Nat. Acad. Sci., *7*, 1895, 452.) From water.

Bacillus diastaticus Boyarska. (Izvestia Acad. Sci., U. S. S. R., Biol. Ser., 1941.) Thermophilic.

Bacillus disciformans Zimmermann. (Zimmermann, Bakt. unserer Trink. u. Nutzwässer, Chemnitz, II Reihe, 1894, 48; *Bacterium disciformans* Lehmann and Neumann, Bakt. Diag., 1 Aufl., *2*, 1896, 238.) From waste water. Apparently not identical with *Bacillus disciformis* Gräfenhan, although the name suggests possible relationship.

Bacillus disciformis Gräfenhan. (Inaug. Diss., Halle, 1891, 1.) From water. From the description, this organism may be *Bacillus subtilis*.

Bacillus distortus (Duclaux) Trevisan. (*Tyrothrix distortus* Duclaux, Ann. Inst. Nat. Agron., *4*, 1882, 23; Trevisan, I generi e le specie delle Batteriacee, 1889, 16.) From milk.

Bacillus dobelli Duboscq and Grassé. (Arch. Zool. Expér. et Gén., *66*, 1927, 487; *Bacillus* (*Flexilis*) *dobelli* Duboscq and Grassé, *ibid.*, 487.) Similar to *Bacillus flexilis* Dobell. Found in rectum of a termite (*Calotermes* (*Glyptotermes*) *iridipennis*). These authors suggest that *Bacillus flexilis* Dobell, *Bacillus butschlii* Schaudinn and *Bacillus dobelli* be grouped under the name *Flexilis*.

Bacillus duclauxii (Miquel) Chester. (*Bacillus ureae* Miquel, Bull. Soc. Chim. d. Paris, *31*, 1879, 391; *Urobacillus duclauxii* sive *Bacillus ureae β* Miquel, Ann. d. Microg., *2*, 1889–1890, 53, 122 and 145; Chester, Ann. Rept. Del. Col. Agr. Exp. Sta., *10*, 1898, 123.) From water and soil.

Bacillus dysodes Zopf. (Die Spaltpilze, 3 Aufl., 1885, 90.) From fermenting dough.

Bacillus elegans Heigener. (Cent. f. Bakt., II Abt., *93*, 1935, 103.) Four cultures isolated from soil, one from Jugoslavia and three from Germany.

Bacillus emulsionis Beijerinck. (Folia Microbiol., *1*, 1912, 377; see Perquin, Jour. Microbiol. and Serol., *6*, 1940, 226.) Produces slime in sucrose solutions.

Bacillus encephaloides Trevisan. (Bacille de l'air *f*, Babes, in Cornil and Babes, Les Bactéries, 1886, 150; Trevisan, I generi e le specie delle Batteriacee, 1889, 20.) From the air.

Bacillus enterothrix Collin. (Arch. Zool. Expér. et Gén., *51*, 1913, Notes and Revue, No. 3.) Found in the rectum of toad tadpoles (*Alytes sp.*).

Bacillus epidermidis (Bizzozero) Bordoni-Uffreduzzi. (*Leptothrix epidermi-*

dis Bizzozero, Arch. f. path. Anat., *98*, 1884, 441; Bordoni-Uffreduzzi, Fortschr. d. Med., *4*, 1886, 156; Carcinombacillus, Scheurlen, Deutsche med. Wochnschr., 1887, 1083; *Bacillus mesentericus rubiginosus* Senger, Cent. f. Bakt., *3*, 1888, 603; *Bacillus bizzozerianus* Trevisan, I generi e le specie delle Batteriacee, 1889, 14; *Bacillus scheurleni* Dyar, Ann. N. Y. Acad. Sci., *8*, 1895, 367.) From the human mouth and skin. Macé (Traité pratique de Bact., 4th ed., 1901, 1071) says that this organism is the ordinary potato bacillus, i.e., *Bacillus vulgatus*.

Bacillus epiphytus ZoBell and Upham. (Bull. Scripps Inst. of Oceanography, Univ. Calif., *5*, 1944, 266.) Central spores. Found associated with marine phytoplankton.

Bacillus erodens Ravenel. (Mem. Nat. Acad. Sci., *8*, 1896, 35.) From soil.

Bacillus esterificans Maassen. (Arb. a. d. kaiserl. Gesundheitsamte, *15*, 1899, 504; *Plectridium esterificans* Huss, Cent. f. Bakt., II Abt., *19*, 1907, 52.) Found in a solution of decomposing litmus; also isolated from butter.

Bacillus evanidus Grohmann. (Morphologisch-biologische Beiträge zur Kenntnis der Wasserstoffbakterien, Inaug. Diss., Univ. Leipzig, 1923; Cent. f. Bakt., II Abt., *61*, 1924, 207; Ruhland and Grohmann, Jahrb. Wissensch. Botanik, *63*, 1924, 321.) Oxidizes hydrogen in the presence of oxygen to form water. Presumably widely distributed in soil.

Bacillus exiguus Saito. (Jour. Coll. Sci., Imp. Univ., Tokyo, *23*, Art. 15, 1908, 44.) Isolated 3 times from garden air.

Bacillus exilis Bartels. (Cent. f. Bakt., II Abt., *103*, 1940, 29.) Growth in media containing M/100 phenol. Eight strains isolated from soil.

Bacillus fastidiosus den Dooren de Jong. (Cent. f. Bakt., II Abt., *79*, 1929, 344.) Six strains isolated from unheated garden soil.

Bacillus ferrigenus Bargaglio-Petrucci. (Nuovo Giornale botanico italiano, 1913, 1914, 1915; quoted from De Rossi, Microbiol. Agraria e Technica, 1927, 904.) A facultative thermophile, growing up to 65° to 70°C.

Bacillus festinus McBeth. (Soil Sci., *1*, 1916, 451.) Filter paper decomposed to a grayish-white felt-like mass. From soil in California.

Bacillus filamentosus Klein. (Klein, see Migula, Syst. d. Bakt., *2*, 1900, 285; *Bacterium filamentosum* Burchard, Arb. bakt. Inst. Karlsruhe, *2*, Heft 1, 1902, 22.)

Bacillus filaris Migula. (Bacillus No. XI, Flügge, Ztschr. f. Hyg., *17*, 1894, 296; *Bacillus lactis* No. XI, Kruse, in Flügge, Die Mikroorganismen, 3 Aufl., *2*, 1896, 209; Migula, Syst. d. Bakt., *2*, 1900, 579; *Bacillus aromaticus* Chester, Man. Determ. Bact., 1901, 276; not *Bacillus aromaticus* Pammell, Bull. No. 21, Iowa Agr. Exp. Sta., 1893, 792; not *Bacillus aromaticus* Grimm, Cent. f. Bakt., II Abt., *8*, 1902, 584.) From milk.

Bacillus filicolonicus ZoBell and Upham. (Bull. Scripps Inst. of Oceanography, Univ. Calif., *5*, 1944, 270.) Subterminal spores. From sea water and marine mud.

Bacillus filiformis (Duclaux) Trevisan. (*Tyrothrix filiformis* Duclaux, Ann. Inst. Nat. Agron., *4*, 1882, 23; Trevisan, I generi e le specie delle Batteriacee, 1889, 16; not *Bacillus filiformis* Tils, Ztschr. f. Hyg., *9*, 1890, 317; not *Bacillus filiformis* Migula, Syst. d. Bakt., *2*, 1900, 587.) From cheese.

Bacillus fissuratus Ravenel. (Mem. Nat. Acad. Sci., *8*, 1896, 38.) From soil.

Bacillus fitzianus Zopf. (Fitz, Ber. d. deutsch. chem. Gesellsch., *6*, 1873, 48; *ibid.*, *9*, 1876, 1348; *ibid.*, *10*, 1877, 276; Glycerinaethylbacterie, Buchner, in Nägeli, Untersuch. ü. niedere Pilze, 1882, 220; Zopf, Die Spaltpilze, 1 Aufl., 1883, 52; *Bacterium fitzianum* Zopf, Die Spaltpilze, 2 Aufl., 1884, 49.) From boiled hay infusions. Forms butyric acid.

Bacillus flagellifer Migula. (Bacillus No. VI, Flügge, Ztschr. f. Hyg., *17*, 1894, 294; *Bacillus lactis* No. VI, Kruse, in Flügge, Die Mikroorganismen, 3 Aufl., *2*, 1896, 209; Migula, Syst. d. Bakt.,

2, 1900, 581; *Bacillus rudis* Chester, Man. Determ. Bact., 1901, 279.) From milk.

Bacillus flavescens Weiss. (Weiss, Arb. bakt. Inst. Karlsruhe, *2*, Heft 3, 1902, 258; not *Bacillus flavescens* Pohl, Cent. f. Bakt., *11*, 1892, 144.) From brewer's grains. Uncommon.

Bacillus flavidus Stührk. (Cent. f. Bakt., II Abt., *93*, 1935, 185; not *Bacillus flavidus* Fawcett, Rev. Indust. y Agrico. de Tucuman, *13*, 1922, 5; not *Bacillus flavidus* Morse, Jour. Inf. Dis., *11*, 1912, 284.) Good growth on Ca n-butyrate agar. One culture isolated from soil from Egypt.

Bacillus flavidus alvei Klamann. (Bienenwirtschaftl. Cent., Hanover, 1890, No. 2.) Associated with foulbrood of bees.

Bacillus flavoviridis Migula. (Maschek, Bakt. Untersuch. d. Leitmeritzer Trinkwässer, Leitmeritz, 1887; Migula, Syst. d. Bakt., *2*, 1900, 821.) From water.

Bacillus flexilis Dobell. (Quart. Jour. Microsc. Sci., *52*, 1908, 121; Arch. f. Protistenk., *26*, 1912, 117.) Reported as being similar to *Bacillus bütschlii* Schaudinn although only half its size. From the large intestine of frogs (*Rana temporaria*) and toads (*Bufo vulgaris*).

Bacillus flexus Batchelor. (Jour. Bact., *4*, 1919, 23.) Resembles *Bacillus megatherium*. From intestinal contents of a child.

Bacillus fluorescens undulatus Ravenel. (Mem. Nat. Acad. Sci., *8*, 1896, 20.) From soil.

Bacillus foliaceus Migula. (*Bacillus mesentericus fuscus* Flügge, Die Mikroorganismen, 2 Aufl., 1886, 321; Bacillus No. IV, Flügge, Ztschr. f. Hyg., *17*, 1894, 294; *Bacillus lactis* No. IV, Kruse, in Flügge, Die Mikroorganismen, 3 Aufl., *2*, 1896, 208; Migula, Syst. d. Bakt., *2*, 1900, 582.) From milk, air and soil.

Bacillus formosus Heigener. (Cent. f. Bakt., II Abt., *93*, 1935, 101; not *Bacillus formosus* Ravenel, Mem. Nat. Acad. Sci., *8*, 1896, 12.) One culture isolated from soil from Montenegro.

Bacillus foutini Chester. (Bacillus D, Foutin, Cent. f. Bakt., *7*, 1890, 373; Chester, Man. Determ. Bact., 1901, 285.) From hail.

Bacillus frankei (sic) DeToni and Trevisan. (Sarkombacillen, Francke, Münch. med. Wochnschr., 1888, No. 4; abst. in Cent. f. Bakt., *3*, 1888, 601; DeToni and Trevisan, in Saccardo, Sylloge Fungorum, *8*, 1889, 967.) From cases of sarcoma.

Bacillus freudenreichii (Miquel) Chester. (*Urobacillus freudenreichii* sive *Bacillus ureae* γ Miquel, Ann. d. Micrographie, *2*, 1890, 367 and 488; Chester, Ann. Rept. Del. Col. Agr. Exp. Sta., *10*, 1898, 110.) Löhnis (Cent. f. Bakt., II Abt., *14*, 1905, 719) considered this a variety of *Bacillus pumilus*. Gibson (Jour. Bact., *29*, 1935, 493) believed it belonged to the *Bacillus pasteurii* group although no authentic cultures were available. From soil.

Bacillus frutodestruens Madhok and Ud-Din. (Indian Jour. Agr. Sci., *13*, 1943, 129.) Causes a rot of tomato fruit.

Bacillus funicularis Kluyver and Van Niel. (Planta, Arch. f. wissensch. Botanik, *2*, 1926, 507.) Exhibits contact irritability. From soil.

Bacillus furvus Goadby. (Dental Cosmos, *42*, 1900, 322.) From the mouth. Associated with dental caries.

Bacillus (*Streptobacter*) *fusisporus* Schroeter. (In Cohn, Krypt. Flora v. Schlesien, *3*, 1, 1886, 161.) From waste water in a sugar factory.

Bacillus fusus Batchelor. (Jour. Bact., *4*, 1919, 27.) Said to resemble *Bacillus centrosporus*, i.e., *Bacillus brevis*. From feces.

Bacillus gangliformis Ravenel. (Ravenel, Mem. Nat. Acad. Sci., *8*, 1896, 34; *Bacterium gangliforme* Chester, Man. Determ. Bact., 1901, 193.) From soil.

Bacillus gangraenae Chester. (*Bacillus gangraenae pulpae* Arkövy, Cent. f. Bakt., *23*, 1897, 921; Chester, Man. Determ. Bact., 1901, 275; not *Bacillus gangraenae* Tilanus, Nederl. Tijdschr. v.

Geneeskunde, *21*, 1885, 110.) Associated with gangrene of tooth pulp and caries of teeth.

Bacillus gasoformans Pammel. (Pammel, Cent. f. Bakt., II Abt., *2*, 1896, 642; not *Bacillus gasoformans* Eisenberg, Bakt. Diag., 3 Aufl., 1891, 107; *Bacillus pammelii* Chester, Man. Determ. Bact., 1901, 270.) From cheese.

Bacillus gelatinosus Migula. (*Bacterium gelatinosum betae* Glaser, Cent. f. Bakt., II Abt., *1*, 1895, 879; Migula, Syst. d. Bakt., *2*, 1900, 805.) Produces slime in sucrose solutions. Probably a variety of *Bacillus vulgatus* according to Sacchetti (Cent. f. Bakt., II Abt., *95*, 1936, 115).

Bacillus geniculatus (Duclaux) Trevisan. (*Tyrothrix geniculatus* Duclaux, Ann. Inst. Nat. Agron., *4*, 1882, 23; Trevisan, I generi e le specie delle Batteriacee, 1889, 16; not *Bacillus geniculatus* De Bary, Inaug. Diss., Strassburg, Leipzig, 1885; not *Bacillus geniculatus* Wright, Mem. Nat. Acad. Sci., *7*, 1894, 459; *Bacillus gonatodes* DeToni and Trevisan, in Saccardo, Sylloge Fungorum, *8*, 1889, 964; *Bacterium geniculatum* Migula, Syst. d. Bakt., *2*, 1900, 322.) From milk.

Bacillus gigas (Koch) Trevisan. (*Streptobacteria gigas-pericardii* Billroth, Die Vegetationsformen von Coccobacteria septica, Berlin, 1874, 60; *Streptobacteria gigas* Koch, in Cohn, Beitr. z. Biol. d. Pflanz., *2*, Heft 3, 1877, 429; *Metallacter gigas* Trevisan, Batter. ital., 1879, 25; Trevisan, Atti. d. Accad. Fis.-Med.-Stat., Milan, Ser. 4, *3*, 1886, 96; not *Bacillis gigas* van der Goot, Med. Proefstation voor de Java Suikerindust., pt. 5, No. 10, 1915, 284; not *Bacillus gigas* Zeissler and Rassefeld, Arch. f. wiss. u. prakt. Tierheilk., *59*, 1929, 419.) From pericardial exudate.

Bacillus ginglymus Ravenel. (Mem. Nat. Acad. Sci., 8, 1896, 37.) From soil.

Bacillus glaciformis Wilhelmy. (Arb. bakt. Inst. Karlsruhe, *3*, 1903, 29.) From meat extract.

Bacillus globifer Bartels. (Cent. f. Bakt., II Abt., *103*, 1940, 26.) Growth on media containing M/100 phenol. Author considers it similar to *Bacillus alvei*. Five strains isolated from soil.

Bacillus glutinis Patrick and Werkman. (Iowa State Coll. Jour. Sci., *7*, 1933, 414.) Ferments xylan. Two strains isolated from decayed apple wood.

Bacillus glycinophilus Rippel. (Rippel, Arch. f. Mikrobiol., *8*, 1937, 42; also see Rippel and Nabel, *ibid.*, *10*, 1938, 359.) From intestines of cattle. Fresh cultures on agar form protein from glycine and glucose.

Bacillus gossypina Stedman. (Alabama Agr. Exp. Sta. Bul. 55, 1894, 6; Earle, Alabama Agr. Exp. Sta. Bul. 107, 1899, 311.) Reported as cause of boll rot on cotton (*Gossypium sp.*)

Bacillus granularis Stührk. (Cent. f. Bakt., II Abt., *93*, 1935, 180.) Very good growth on Ca n-butyrate agar. One culture isolated from garden soil in Germany.

Bacillus granulosus Russell. (Russell, Ztschr. f. Hyg., *11*, 1892, 194; *Bacterium granulosum* Chester, Man. Determ. Bact., 1901, 194.) From mud from the Gulf of Naples.

Bacillus grossus Migula. (Bacterienart No. 13, Lembke, Arch. f. Hyg., *26*, 1896, 308; Migula, Syst. d. Bakt., *2*, 1900, 570.) From the intestines of infants.

Bacillus gryllotalpae Metalnikov and Meng. (Compt. rend. Acad. Sci., Paris, *201*, 1935, 367.) From diseased larvae of the cricket (*Gryllotalpa gryllotalpa*).

Bacillus guano Stapp. (Cent. f. Bakt., II Abt., *51*, 1920, 29.) From soil previously fertilized with guano.

Bacillus gummosus Happ. (Bakt. und Chem. Untersuch. über die schleimige Gahrung. Univ. Basel, 1893, 34; abst. in Cent. f. Bakt., *14*, 1893, 175.) From digitalis infusions. Presumably a mucoid form of a common spore-former. See *Bacterium gummosum* Ritsert.

Bacillus harai Hori and Miyake. (Rpt. Imp. Agr. Exp. Sta. Nishigahara, *38*,

1911, 69.) Pathogenic for willow (*Salix sp.*).

Bacillus hessii (Guillebeau) Kruse. (*Bacterium hessii* Guillebeau, Landw. Jahrb. d. Schweiz, *5*, 1891, 138; Kruse, in Flügge, Die Mikroorganismen, 3 Aufl., *2*, 1896, 210.) There is some question whether the original culture was a spore-former or whether it was mixed with one of the common slimy milk organisms. From slimy milk.

Bacillus hirudinis Schweizer. (Arch. f. Mikrobiol., *7*, 1936, 235.) From the digestive slime of leeches (*Hirudo medicinalis* and *Hirudo officinalis*).

Bacillus hollandicus Stapp. (Cent. f. Bakt., II Abt., *51*, 1920, 47.) From soil from Delft.

Bacillus hoplosternus Paillot. (Compt. rend. Acad. Sci., Paris, *163*, 1916, 774; Ann. Inst. Past., *33*, 1919, 403.) Isolated once from the body fluid of a June bug. Pathogenic for several species of insects.

Bacillus imminutus McBeth. (Soil Sci., *1*, 1916, 455.) Growth only in the presence of cellulose. From ten different soils of California.

Bacillus immobilis Steinhaus. (Jour. Bact., *42*, 1941, 783.) The author states that it probably belongs to the *Bacillus adhaerens* group. From rectum of larvae of the sphinx moth (*Ceratomia catalpae*).

Bacillus imomarinus ZoBell and Upham. (Bull. Scripps Inst. of Oceanography, Univ. Calif., *5*, 1944, 265.) Subterminal spores. From marine bottom deposits in shoal waters.

Bacillus indifferens Soriano. (Thesis, Univ. Buenos Aires, 1935, 565.) One strain isolated from soil.

Bacillus infantilis Kendall. (Jour. Biol. Chem., *5*, 1909, 419 and 439.) From the intestine in cases of infantilism. Saprophytic.

Bacillus intermittens Wilhelmy. (Arb. bakt. Inst. Karlsruhe, *3*, 1903, 23.) From meat extract.

Bacillus intrapallans Forbes. (Bull. Illinois State Lab. Natur. Hist., Art. IV, 1886, 283, 288 and 297.)

Bacillus jubatus Bartels. (Cent. f. Bakt., II Abt., *103*, 1940, 24.) Very good growth on media containing M/50 phenol. Nine strains isolated from soil.

Bacillus kaleidoscopicus Wilhelmy. (Arb. bakt. Inst. Karlsruhe, *3*, 1903, 31.) From meat extract.

Bacillus kefir Kuntze. (Cent. f. Bakt., II Abt., *24*, 1909, 116.) From kefir, a Caucasian milk beverage.

Bacillus kermesinus Migula. (Karminroter Bacillus, Tataroff, Inaug. Diss., Dorpat, 1891, 67; Migula, Syst. d. Bakt., *2*, 1900, 858.) From water.

Bacillus kildini Issatchenko. (Recherches sur les Microbes de l'Océan Glacial Arctique. Petrograd, 1914.) From sea water.

Bacillus koubassoffii Chester. (Bacillus der krebsartigen Neubildungen, Koubassoff, Vortrag. Moskauer Militärärztlichen Verein, 1888, No. 22; abst. in Cent. f. Bakt., *7*, 1890, 317; Chester, Man. Determ. Bact., 1901, 282.) From cancerous growths of the human stomach.

Bacillus lacca Kern. (Arb. bakt. Inst. Karlsruhe, *1*, Heft 4, 1896, 411.) From the stomachs and intestines of birds.

Bacillus lactis-albus Chester. (*Bacillus lactis albus* Sternberg, Man. of Bact., 1893, 680; Chester, Man. Determ. Bact., 1901, 277.) From milk.

Bacillus lactucae Voglino. (Ann. R. Accad. Agr. Torino, *46*, 1903, 25.) Pathogenic for lettuce (*Lactuca sativa*).

Bacillus lasiocampa Brown. (Amer. Museum Novitates, No. 251, 1927, 7.) Said to belong to *Bacillus subtilis* group. From ovaries and egg tubes of tent caterpillar moth.

Bacillus latvianus Kalnins. (Latvijas Univ. Raksti, Serÿa I, No. 11, 1930, 265.) Cellulose attacked at 34°C but not at 37°C. Probably from soil.

Bacillus lautus Batchelor. (Jour. Bact., *4*, 1919, 30.) One culture from feces.

Bacillus legrosii Hauduroy et al. (Legros, Thèse Méd. Paris, 1902; Hauduroy et al., Dict. d. Bact. Path., 1937, 43.)

Facultative anaerobe producing gaseous gangrene. From a gaseous suppuration.

Bacillus leguminiperdus von Oven. (Cent. f. Bakt., II Abt., *16*, 1906, 67; *Bacterium leguminiperdum* Stevens, The Fungi which Cause Plant Disease, 1913, 28.) Pathogenic for lupine (*Lupinus sp.*), kidney bean (*Phaseolus vulgaris*), pea (*Pisum sativum*), tomato (*Lycopersicum esculentum*).

Bacillus lehmanni Herter. (Microbe 5A, Choukévitch, Ann. Inst. Past., *25*, 1911, 350; Herter, Just's Botan. Jahresber., *39*, 2 Abt., Heft 4, 1915, 748.) From the large intestine of the horse.

Bacillus lekitosis Perlman. (N. Y. State Dept. Agr. and Markets, Ann. Rept., 1931, 115.) Egg lecithin hydrolyzed completely by powerful extracellular enzyme. From contaminated sample of whole mixed eggs.

Bacillus lesagei Trevisan. (Bacille de la diarrhée verte des enfants, Lesage, Bull. Acad. Méd. Paris, Oct. 25, 1887; Trevisan, I generi e le specie delle Batteriacee, 1889, 14.) From the intestine of infants.

Bacillus levaniformans Greig Smith. (Proc. Linn. Soc. New South Wales, *26*, 1901, 589, 674 and 684; Cent. f. Bakt., II Abt., *8*, 1902, 596.) Produces slime in sucrose solutions. Probably a variety of *Bacillus vulgatus* according to Sacchetti (Cent. f. Bakt., II Abt., *95*, 1936, 115).

Bacillus licheniformis (Weigmann) Chester. (Bacterie a, Weigmann, Cent. f. Bakt., II Abt., *2*, 1896, 155; *Clostridium licheniforme* Weigmann, *loc. cit.*, *4*, 1898, 822; Chester, Man. Determ. Bact., 1901, 287; see also Gibson, Soc. Agric. Bact. (British); Abstr. Proc., 1927, Paper No. 10; Gibson and Topping, *ibid.*, 1938, 43; Gibson, *ibid.*, 1943, 13.) Gibson places this with *Bacillus subtilis* although it was originally described as being Gram-negative and forming clostridial sporangia. Spore germination polar.

Bacillus lichenoides Grohmann. (Morphologisch-biologische Beiträge zur Kenntnis der Wasserstoffbakterien, Inaug. Diss., Univ. Leipzig, 1923; Cent. f. Bakt., II Abt., *61*, 1924, 267; Ruhland and Grohmann, Jahrb. wissensch. Botanik, *63*, 1924, 321.) Oxidizes hydrogen in the presence of oxygen to form water. Presumably widely distributed in soil.

Bacillus lignivorans Patrick and Werkman. (Iowa State Coll. Jour. Sci., *7*, 1933, 410.) Ferments xylan. One culture isolated from decayed maple wood.

Bacillus lignorum Patrick and Werkman. (Iowa State Coll. Jour. Sci., *7*, 1933, 410.) Ferments xylan. One culture isolated from decayed apple wood.

Bacillus limnophilus Stührk. (Cent. f. Bakt., II Abt., *93*, 1935, 190.) Good growth on Ca n-butyrate agar. One culture isolated from soil of Germany.

Bacillus lingardi Trevisan. (Bacillus de la stomatite ulcereuse du veau, Lingard and Batt; Trevisan, I generi e le specie delle Batteriacee, 1889, 14.) From ulcerations on the tongue and mucous membrane of the mouth of calves.

Bacillus lividus Zimmermann. (Bakt. unserer Trink- u. Nutzwässer, Chemnitz, II Reihe, 1894, 18; not *Bacillus lividus* Voges, Cent. f. Bakt., *14*, 1893, 303.) From water.

Bacillus longior Saito. (Jour. Coll. Sci., Imp. Univ., Tokyo, *23*, Art. 15, 1908, 57.) Isolated once from garden air.

Bacillus longus Migula. (Bacillus No. VII, Flügge, Ztschr. f. Hyg., *17*, 1894, 296; *Bacillus lactis* No. VII, Kruse, in Flügge, Die Mikroorganismen, 3 Aufl., *2*, 1896, 209; Migula, Syst. d. Bakt., *2*, 1900, 581; not *Bacillus longus* Chester, Man. Determ. Bact., 1901, 303; *Bacillus plicatus* Chester, *ibid.*, 275; not *Bacillus plicatus* Frankland and Frankland, Philos. Trans. Royal Soc. London, *178*, B, 1887, 273; not *Bacillus plicatus* Zimmermann, Bakt. unserer Trink- u. Nutzwässer, Chemnitz, I Reihe, 1890, 54; not *Bacillus plicatus* Deetjen, Inaug. Diss., Würzburg, 1890; not *Bacillus plicatus* Copeland, Rept. Filtration Commission, Pittsburgh, 1899, 348.) From milk.

Bacillus loxosporus Burchard. (Arb. bakt. Inst. Karlsruhe, *2*, Heft 1, 1902, 49.) From the air. Synonym of *Bacillus simplex* according to Gottheil, Cent. f. Bakt., II Abt., *7*, 1901, 633.

Bacillus luteus Garbowski. (*Bacillus luteus sporogenes* Smith and Baker, Cent. f. Bakt., II Abt., *4*, 1898, 788; Garbowski, Cent. f. Bakt., II Abt., *19*, 1907, 641.) From two samples of beet sugar.

Bacillus lutzae Brown. (Amer. Museum Novitates, No. 251, 1927, 8.) Pathogenic for certain flies. Dying individuals of the green blow fly (*Lucilia sericata*) yielded pure cultures.

Bacillus maculatus Stührk. (Cent. f. Bakt., II Abt., *93*, 1935, 184.) Good growth on Ca n-butyrate agar. Two cultures isolated from soils from Cuba and Germany.

Bacillus maïdis Paltauf and Heider. (Paltauf and Heider, Wiener med. Jahrb., *3*, 1888, 383; Paltauf, Med. Jahrb., No. 8, 1889.) From an infusion of maize; also from feces in cases of pellagra. This species was originally described by Cuboni, probably in the Rendic. R. Accad. dei Lincei, *1*, 1886. It was later shown to be a spore-former of the *Bacillus mesentericus* group. It was quite different from the organism isolated by Tataroff (*Pseudomonas maidis* Migula) and identified by him as *Bacillus maidis*.

Bacillus malakofaciens von Wahl. (Cent. f. Bakt., II Abt., *16*, 1906, 499.) Reported to be similar in morphology and physiology to *Bacillus asterosporus*. From preserved asparagus and from green beans.

Bacillus maritimus Russell. (Russell, Bot. Gazette, *18*, 1893, 445; *Bacterium maritimum* Chester, Man. Determ. Bact., 1901, 189.) From sea-mud.

Bacillus mazun Weigmann, Gruber and Huss. (Cent. f. Bakt., II Abt., *19*, 1907, 72.) From the Armenian milk product, mazun.

Bacillus mediosporus Migula. (Bacillus No. VIII, Flügge, Ztschr. f. Hyg., *17*, 1894, 296; *Bacillus lactis* No. VIII, Kruse, in Flügge, Die Mikroorganismen, 3 Aufl., *2*, 1896, 209; Migula, Syst. d. Bakt., *2*, 1900, 580; *Bacillus magnus* Chester, Man. Determ. Bact., 1901, 276.) From milk.

Bacillus medio-tumescens Saito. (Jour. Coll. Sci. Imp. Univ., Tokyo, *23*, Art. 15, 1908, 45.) Isolated twice from garden air.

Bacillus megatherium Ravenel. (Ravenel, Mem. Nat. Acad. Sci., *8*, 1896, 11; not *Bacillus megatherium* De Bary, Vergleich. Morph. u. Biol. d. Pilze, 1884, 499; *Bacillus megatherium* var. *ravenelii* Chester, Man. Determ. Bact., 1901, 271.) From soil.

Bacillus melanosporus Schroeter. (Eine *Bacillus* Art, Eidam, Beitr. z. Biol. d. Pflanz., *1*, 3, 1875, 216; Schroeter, in Cohn, Kryptog. Flora v. Schlesien, *3*, 1, 1886, 159.) From cooked potato.

Bacillus melonis Patrick and Werkman. (Iowa State Coll. Jour. Sci., *7*, 1933, 411; not *Bacillus melonis* Giddings, Vermont Agr. Exp. Station Bull. 148, 1910, 413.) Ferments xylan. One culture isolated from decayed watermelon.

Bacillus mesentericus fuscus consistens Dyar. (Ann. N. Y. Acad. Sci., *8*, 1895, 373.) Found as a contamination in a milk culture.

Bacillus mesentericus fuscus granulatus Dyar. (Ann. N. Y. Acad. Sci., *8*, 1895, 373.) Found abundantly in a jar of sterilized milk.

Bacillus mesentericus roseus Zimmermann. (Bakt. unserer Trink- u. Nutzwässer, Chemnitz, *2*, 1894, 26.) From water. Zimmermann received this culture from Kràl under the above name. Kràl (Sammlung v. Mikroorganismen, Prague, 1900, 7) lists it as a synonym of *Bacillus mesentericus ruber* Globig.

Bacillus mesentericus vulgatus mucosus Ivanovics. (Cent. f. Bakt., I Abt., Orig., *142*, 1938, 52.) Author believed it to be identical or near to *Bacillus vulgatus*

but produces much slime. From drainage water.

Bacillus mesenterioides Deetjen. (Inaug. Diss., Würzburg, 1890.) From sausage.

Bacillus micans Wilhelmy. (Arb. bakt. Inst. Karlsruhe, *3*, 1903, 30.) From meat extract.

Bacillus milii (sic) Howard. (Gleanings in Bee Culture, *28*, 1900, 124.) From black brood of the honey bee (*Apis mellifera*).

Bacillus mitochrondrialis Alexeieff. (Arch. f. Protist., *49*, 1924, 399.) From horse manure.

Bacillus modestus Schieblich. (Cent. f. Bakt., I Abt., Orig., *124*, 1932, 269.) Prefers carbohydrate media and 37°C. From grass and meadow plants.

Bacillus monachae (von Tubeuf) Eckstein. (Bacillus B, Hofmann, Die Schlaffsucht (Flacherie) der Nonne (*Liparis monacha*), 1891, Frankfort am Main; *Bacterium monachae* von Tubeuf, Forstl. naturwissensch. Ztschr., *1*, 1892, 34, 277; Eckstein, Ztschr. f. Forst- u. Jagdwesen, *26*, 1894, 6.) From diseased caterpillars of the nun moth (*Lymantria monacha*).

Bacillus montanus Werner. (Cent. f. Bakt., II Abt., *87*, 1933, 458.) Good growth on Ca n-butyrate agar. One culture isolated from soil of Germany.

Bacillus moulei DeToni and Trevisan. (Bacille des viandes à odeur de beurre rance des halles de Paris, Nocard and Moulé, Recueil de médecine vétér., Sér. 7, *6*, 18—, 67; DeToni and Trevisan, in Sacardo, Sylloge Fungorum, *8*, 1889, 971.) From spoiled meat.

Bacillus mucilaginosus Migula. (Happ, Inaug. Diss., Berlin, 1893, 28; Migula, Syst. d. Bakt., *2*, 1900, 696.) From a slimy fermentation.

Bacillus mucosus Zimmerman. (Bakt. unserer Trink- u. Nutzwässer, Chemnitz, II Reihe, 1894, 8; *Bacterium mucosum* Migula, Syst. d. Bakt., *2*, 1900, 315.) From water.

Bacillus mucronatus Saito. (Jour. Coll. Sci., Imp. Univ., Tokyo, *23*, Art. 15, 1908, 58.) Isolated twice from garden air.

Bacillus multipediculus flavus Zimmermann. (Bakt. unserer Trink- u. Nutzwässer, Chemnitz, II Reihe, 1894, 42.) From water.

Bacillus muralis Tomaschek. (Botan. Zeit., *46*, 1887, 665.)

Bacillus mutabilis Soriano. (Estudio sistematico de algunas bacterias esporuladas aerobias, Thesis, Univ. Buenos Aires, 1935, 570.) Four strains isolated from fecal matter and Argentine soils.

Bacillus myxodens Burchard. (Arb. bakt. Inst. Karlsruhe, *2*, Heft 1, 1898, 41.) From beer yeast.

Bacillus nebulosus Goresline. (Goresline, Jour. Bact., *27*, 1934, 72; not *Bacillus nebulosus* Wright, Mem. Nat. Acad. Sci., 7, 1894, 465; not *Bacillus nebulosus* Halle, Thèse de Paris, 1898; not *Bacillus nebulosus* Vincent, Ann. Inst. Past., *21*, 1907, 69; not *Bacillus nebulosus gazogenes* Jacobson, Ann. Inst. Past., *22*, 1908, 300.) From a trickling filter receiving creamery wastes.

Bacillus neumanni Herter. (Microbe 5B, Choukévitch, Ann. Inst. Past., *25*, 1911, 350; Herter, Just's Botan. Jahresber., *39*, 2 Abt., Heft 4, 1915, 748.) From the large intestine of the horse.

Bacillus nigrescens Bartels. (Cent. f. Bakt., II Abt., *103*, 1940, 22.) Good growth on media containing M/25 phenol. Three strains isolated from soil.

Bacillus nigricans Kern. (Arb. bakt. Inst. Karlsruhe, *1*, Heft 4, 1896, 428.) From the stomach of a bird.

Bacillus nitidis Heigener. (Cent. f. Bakt., II Abt., *93*, 1935, 99.) One culture isolated from soil from Washington, D. C.

Bacillus nitri Ambrož. (Cent. f. Bakt., I Abt., Orig., *51*, 1909, 193.) Used for cytological studies because of its large size. Found on gelatin plates poured for the isolation of yeasts.

Bacillus nitroxus Beijerinck. (Cent. f. Bakt., II Abt., *25*, 1909, 45.) In the absence of air forms N gas, CO_2, and N_2O in nitrate broth. Under aerobic condi-

tions only a weak reduction. From garden soil.

Bacillus nobilis Adametz. (See Freudenreich, Cent. f. Bakt., II Abt., *7*, 1901, 857; *ibid.*, *8*, 1902, 674.) This organism was sold under the name Tyrogen; it was said to play a part in the ripening of hard cheese. This was doubted by Freudenreich who identified it as one of the *Tyrothrix* group. Original description apparently in Osterreichen Mokerei-Zeitung, Nov. 15, 1900; Dec. 1 and 15, 1900; Milchzeitung, No. 48, 1900.

Bacillus novus (Huss) Bergey et al. (*Plectridium novum* Huss, Cent. f. Bakt., II Abt., *19*, 1907, 256; Bergey et al., Manual, 1st ed., 1923, 304.) From sterilized milk.

Bacillus oblongus Eckstein. (Ztschr. f. Forst- u. Jagdwesen, *26*, 1894, 16.) From the larvae of a moth (*Hyponomeuta evonymella*).

Bacillus oehensis Bartels. (Cent. f. Bakt., II Abt., *103*, 1940, 28.) Growth on media containing M/100 phenol. One culture isolated from soil.

Bacillus oleae Schiff-Giorgini. (Cent. f. Bakt., II Abt., *15*, 1905, 203.) Thought to be the cause of tubercles on the olive tree from which it was isolated.

Bacillus omelianskii Serbinoff. (Zhurnal Bolezni Rastenii, Leningrad, *9*, 1915, 105.) Causes a rot of sorghum.

Bacillus ontarioni (Chorine) Steinhaus. (*Bacterium ontarioni* Chorine, Internat. Corn Borer Invest., Sci. Rpts., *2*, 1929, 44; also Ann. Inst. Past., *43*, 1929, 1658; *B. ontarioni* Paillot, *B.* presumably indicates *Bacterium*, see index, p. 522, L'infection chez les insectes, 1933, 134; Steinhaus, Bacteria Associated Extracellularly with Insects, Minneapolis, 1942, 72.) From diseased larvae of the corn borer (*Pyraustra nubilalis* Hb.).

Bacillus oogenes Migula. (*Bacillus oogenes hydrosulfureus α*, Zörkendörfer, Arch. f. Hyg., *16*, 1893, 385; Migula, Syst. d. Bakt., *2*, 1900, 573.) From hens' eggs.

Bacillus opacus Weiss. (Arb. bakt. Inst. Karlsruhe, *2*, Heft 3, 1902, 214.) From bean infusions and fermenting cabbage.

Bacillus orae Werner. (Cent. f. Bakt., II Abt., *87*, 1933, 464.) Weak growth on agar containing calcium salts of formic, acetic, and butyric acids. One culture isolated from European soil.

Bacillus oxylacticus Dyar. (Dyar, Ann. N. Y. Acad. Sci., *8*, 1895, 369; *Bacterium oxylacticus* Chester, Ann. Rept. Del. Col. Agr. Exp. Sta., *9*, 1897, 107.) From air and a culture from Kràl's laboratory labeled *Bacillus oxylacticus*. The latter is given in the Kràl 1900 catalogue as *Bacillus oxalaticus* Zopf and undoubtedly was the organism received by Migula from Zopf and studied by him (Migula, Arb. tech. Hochschule Karlsruhe, *1*, Heft 1, 1894, 139 and Migula, Syst. d. Bakt., *2*, 1900, 538). This is now regarded as having been *Bacillus megatherium* De Bary.

Bacillus pabuli Schieblich. (Cent. f. Bakt., II Abt., *58*, 1923, 204.) Commonly isolated from green and fermenting fodder.

Bacillus pallidus Heigener. (Cent. f. Bakt., II Abt., *93*, 1935, 98.) One strain isolated from soil from New York State.

Bacillus palustris Sickles and Shaw. (Jour. Bact., *28*, 1934, 418; *Rhodobacillus palustris* Sickles and Shaw, Jour. Bact., *38*, 1939, 241.) Decomposes the specific carbohydrate of pneumococcus type III. From swamp and other uncultivated soils.

Bacillus palustris var. *gelaticus* Sickles and Shaw (*loc. cit.*, 419). A variety that decomposes agar slightly. Found only once.

Bacillus paucicutis Burchard. (Arb. bakt. Inst. Karlsruhe, *2*, Heft 1, 1902, 27.) From rye bread.

Bacillus pectocutis Burchard. (Arb. bakt. Inst. Karlsruhe, *2*, Heft 1, 1902, 24.) From the air.

Bacillus pelagicus Russell. (Bot. Gaz., *18*, 1893, 383.) From sea water and marine mud from Woods Hole, Massachusetts.

Bacillus pellucidus Soriano. (Revista

del Instit. Bacteriol., Buenos Aires, *6*, 1935, 567.) Author says colonies resemble *Bacillus simplex*. Habitat probably in soil.

Bacillus peptogenes (Buchanan and Hammer) Bergey et al. (*Bacterium peptogenes* Buchanan and Hammer, Iowa Agr. Exp. Sta. Res. Bull. 22, 1915, 273; Bergey et al., Manual, 1st ed., 1923, 293.) From a tube of litmus milk after autoclaving.

Bacillus peptonans Chester. (*Bacillus lactis peptonans* Sterling, Cent. f. Bakt., II Abt., *1*, 1895, 473; Chester, Man. Determ Bact., 1901, 271.) From milk. Very similar to *Bacillus mesentericus vulgatus* Flügge.

Bacillus peptonificans Lubenau. (Cent. f. Bakt., I Abt., Orig., *40*, 1906, 435.) Similar to *Bacillus subtilis*. Believed to be the cause of an epidemic of gastroenteritis.

Bacillus perlucidulus Saito. (Jour. Coll. Sci., Imp. Univ., Tokyo, *23*, Art. 15, 1908, 43.) Isolated 3 times from garden air.

Bacillus petiolatus Saito. (Jour. Coll. Sci., Imp. Univ., Tokyo, *23*, Art. 15, 1908, 48.) Isolated twice from garden air.

Bacillus phaseoli von Wahl. (Cent. f. Bakt., II Abt., *16*, 1906, 500.) From canned beans.

Bacillus phenolphilos Bartels. (Cent. f. Bakt., II Abt., *103*, 1940, 21.) Good growth on media containing M/50 phenol. One culture isolated from soil.

Bacillus picrogenes Patrick and Werkman. (Iowa State Coll. Jour. Sci., *7*, 1933, 410.) Ferments xylan. One culture isolated from decayed watermelon.

Bacillus piliformis Tyzzer. (Jour. Med. Research, *37*, 1917, 307.) All attempts to cultivate the organism failed except when mixed with a streptotoccus. Considered aerobic by Ford (Textbook of Bact., 1927, 712). Causes fatal disease of Japanese waltzing mice.

Bacillus piscicidus Migula. (*Bacillus piscicidus agilis* Siebert, Gazeta lekarska, 1895, No. 13–17; abst. in Cent. f. Bakt., *17*, 1895, 888; *Bacterium piscicidus agilis* Chester, Ann. Rept. Del. Col. Agr. Exp. Sta., *9*, 1897, 140; Migula, Syst. d. Bakt., *2*, 1900, 652; *Bacillus piscicidus nobilis* (sic) Babes and Riegler, Cent. f. Bakt., II Abt., Orig., *33*, 1902–03, 440.) Cause of a fish epidemic in St. Petersburg.

Bacillus pisi von Wahl. (Cent. f. Bakt., II Abt., *16*, 1906, 502.) From young peas.

Bacillus platychoma Gray and Thornton. (Cent. f. Bakt., II Abt., *73*, 1928, 93.) Phenol is attacked. Three strains isolated from soil.

Bacillus plexiformis Goadby. (Dental Cosmos, *42*, 1900, 322.) From the mouth.

Bacillus plicatus Deetjen. (Deetjen, Inaug. Diss., Würzburg, 1890; not *Bacillus plicatus* Frankland and Frankland, Philos. Trans. Royal Soc. London, *178*, B, 1887, 273; not *Bacillus plicatus* Zimmermann, Bakt. unserer Trink- u. Nutzwässer, Chemnitz, I Reihe, 1890, 54; not *Bacillus plicatus* Copeland, Rept. Filtration Commission, Pittsburgh, 1899, 348; not *Bacillus plicatus* Chester, Man. Determ. Bact., 1901, 275.) From sausage.

Bacillus pollacii Pavarino. (Atti R. Accad. Naz. Lincei Rend. Cl. Sci. Fis. Math. e Nat., *20*, 1911, 233.) Reported to cause depressed spots on leaves of *Odontoglossum citrosmum*.

Bacillus populi Brisi. (Atti Cong. Nat. Ital. Pom. della Soc. Ital. di Sci. Nat. Milano, 1907, 376.) Reported as cause of galls on branches of poplar trees (*Populus sp.*).

Bacillus pseudanthracis Kruse. (Milzbrandähnlicher Bacillus, Burri, Hyg. Rundschau, *4*, 1894, 339; abst. in Cent. f. Bakt., *16*, 1894, 374; Kruse, in Flügge, Die Mikroorganismen, 3 Aufl., *2*, 1896, 233; not *Bacillus pseudanthracis* Wahrlich, Bakteriol. Studien, Petersburg, 1890–91, 26; *Bacillus pseudo-anthracis* Chester, Man. Determ. Bact., 1901, 280.) From South American bran.

Bacillus pseudococcus Migula. (Bacil-

lus No. 11, Pansini, Arch. f. path. Anat., *122*, 1890, 446; Migula, Syst. d. Bakt., *2*, 1900, 557.) From sputum.

Bacillus pseudodiphthericum magnus Ødegaard. (Acta Path. et Microbiol. Scand., *21*, 1944, 451; see Endicott, Biol. Abst., *20*, 1946, 12926.) From the nose of a child suspected of having diphtheria. Resembles *Corynebacterium diphtheriae* in young cultures. Non-pathogenic.

Bacillus pseudofusiformis Saito. (Jour. Coll. Sci., Imp. Univ., Tokyo, *23*, Art. 15, 1908, 47.) Isolated once from garden air.

Bacillus pseudosubtilis Migula. (*Bacillus subtilis similis* Sternberg, Manual of Bact., 1893, 679; Migula, Syst. d. Bakt., *2*, 1900, 618.) From the liver of a yellow fever cadaver.

Bacillus punctiformis Chester. (Bacillus No. 23, Conn, Storrs Agr. Exp. Sta. Rept., 1893, 53; Chester, Man. Determ. Bact., 1901, 284.) From milk.

Bacillus pycnoticus Grohmann. (Cent. f. Bakt., II Abt., *61*, 1924, 261; Ruhland and Grohmann, Jahrb. wissensch. Botanik, *63*, 1924, 321; *Hydrogenomonas pycnotica* Bergey et al., Manual, 3rd ed., 1930, 34.) Oxidizes hydrogen in the presence of oxygen to form water. Presumably widely distributed in soil.

Bacillus quercifolius Deetjen. (Deetjen, Inaug. Diss., Würzburg, 1890; *Bacterium quercifolium* Migula, Syst. d. Bakt., *2*, 1900, 309.) From sausage.

Bacillus rarerepertus Schieblich. (Cent. f. Bakt., I Abt., Orig., *124*, 1932, 269.) From beet leaves.

Bacillus rarus Werner. (Cent. f. Bakt., II Abt., *87*, 1933, 456.) Good growth on Ca n-butyrate agar. One culture isolated from forest soil of Germany.

Bacillus repens Gibson. (Cent. f. Bakt., II Abt., *92*, 1935, 370.) Decomposes urea. Eight strains isolated from soil.

Bacillus reptans Ghosh. (Compt. rend. Soc. Biol., Paris, *86*, 1922, 914.) From a case of appendicitis.

Bacillus retaneus Grohmann. (Morphologisch- biologische Beiträge zur Kenntnis der Wasserstoffbakterien, Inaug. Diss., Univ. Leipzig, 1923; Cent. f. Bakt., II Abt., *61*, 1924, 267; Ruhland and Grohmann, Jahrb. wissensch. Botanik, *63*, 1924, 321.) Oxidizes hydrogen in the presence of oxygen to form water. Presumably widely distributed in soil.

Bacillus retiformis Migula. (Netzbacillus, Maschek, Bakt. Untersuch. d. Leitmeritzer Trinkwässer, Leitmeritz, 1887; Migula, Syst. d. Bakt., *2*, 1900, 712.) From water.

Bacillus robustus Weiss. (Weiss, Arb. bakt. Inst. Karlsruhe, *2*, Heft 3, 1902, 247; not *Bacillus robustus* Blau, Cent. f. Bakt., II Abt., *15*, 1905, 134.) From fermenting beets.

Bacillus ruber Zimmermann. (Zimmermann, Die Bakt. unserer Trink- u. Nutzwässer, Chemnitz, *1*, 1890, 24; not *Bacillus ruber* Cohn, Beitr. z. Biol. d. Pflanz., *1*, Heft 3, 1875, 181; *Bacillus pseudoruber* Migula, Syst. d. Bakt., *2*, 1900, 850; *Erythrobacillus ruber* Holland, Jour. Bact., *5*, 1920, 223, line 15; *Serratia rubra* Bergey et al., Manual, 1st ed., 1923, 92; *Chromobacterium ruber* Topley and Wilson, Princip. of Bact. and Immun., *1*, 1931, 402.) From Chemnitz tap water. Spherical spores. See Manual, 5th ed., 1939, 607 for a description of this species.

Bacillus rufescens Stührk. (Cent. f. Bakt., II Abt., *93*, 1935, 178.) Characterized by good growth on Ca n-butyrate agar. One culture isolated from garden soil of Germany.

Bacillus rufulus Saito. (Jour. Coll. Sci., Imp. Univ., Tokyo, *23*, Art. 15, 1908, 59.) Isolated 3 times from garden air.

Bacillus rugosus Henrici. (Henrici, Arb. bakt. Inst. Karlsruhe, *1*, Heft 1, 1894, 28; not *Bacillus rugosus* Wright, Mem. Nat. Acad. Sci., *7*, 1895, 438; not *Bacillus rugosus* Chester, Man. Determ. Bact., 1901, 220.) From Swiss cheese.

Bacillus rugulosus Stührk. (Cent. f. Bakt., II Abt., *93*, 1935, 181.) One of a

group of species described as growing well on Ca n-butyrate agar. Three strains isolated from soils of Germany, Cuba, and Italy.

Bacillus sacchari Jansc. (Mededeel. uit's Lands. Plantentuin, *9*, 1891, 1.) Reported to cause sereh, a disease affecting sugar cane (*Saccharum officinarum*). Went (Arch. voor de Java Suikerindustrie, 1895, 589) regards this as probably *Bacillus subtilis*.

Bacillus saccharolyticus Nepomnjatschjaja and Libermann. (Jour. f. Mikrobiol., Ukraine, *5*, 1938, 57; abst. in Cent. f. Bakt., II Abt., *101*, 1940, 81.) From plum preserves. A gas-producing rod.

Bacillus saccobranchi Dobell. (Quart. Jour. Micro. Sci., *56*, 1911, 441.) From heart blood of a fish (*Saccobranchus fossilis*).

Bacillus santiagensis Stührk. (Cent. f. Bakt., II Abt., *93*, 1935, 188.) Good growth on Ca n-butyrate agar. One culture isolated from Cuban soil.

Bacillus saprogenes Migula. (*Bacillus saprogenes vini III*, Kramer, Bakteriologie in ihren Beziehungen zur Landwirtschaft, *2*, 1892, 137; Migula, Syst. d. Bakt., *2*, 1900, 572; not *Bacillus saprogenes I*, *II* and *III*, Herfeldt, Cent. f. Bakt., II Abt., *1*, 1895, 77; not *Bacillus saprogenes* Salus, Arch. f. Hyg., *51*, 1904, 115.) From wine.

Bacillus saprogenes Chester. (*Bacillus saprogenes vini VI*, Kramer, Bakteriol. Landwirtsch., *2*, 1892, 139; Chester, Man. Determ. Bact., 1901, 289; not *Bacillus saprogenes* Trevisan, I generi e le specie delle Batteriacee, 1889, 17.) From wine.

Bacillus scaber (Duclaux) Trevisan. (*Tyrothrix scaber* Duclaux, Ann. Inst. Nat. Agron., *4*, 1882, 23; Trevisan, I generi e le specie delle Batteriacee, 1889, 16.) From milk.

Bacillus schottelii Trevisan. (Darmbacillus, Lydtin and Schottelius, Der Rotlauf der Schweine, Weisbaden, 1885, 214; *Bacillus coprogenes foetidus* Flügge, Die Mikroorganismen, 2 Aufl., 1886, 305; Trevisan, I generi e le specie delle Batteriacee, 1889, 17; *Bacterium coprogenes* Migula, Syst. d. Bakt., *2*, 1900, 327; *Bacterium schottelii* Chester, Man. Determ. Bact., 1901, 197.) From the intestinal contents of swine.

Bacillus segetalis Werner. (Cent. f. Bakt., II Abt., *87*, 1933, 467.) Characterized by growth on Ca n-butyrate agar. One strain isolated from soil in Germany.

Bacillus septico-aerobius Hauduroy et al. (Bacille septique aérobie, Legros, Thèse Méd., Paris, 1902; Hauduroy et al., Dict. d. Bact. Path., 1937, 46.) Aerobic, facultative. From a case of acute gaseous gangrene.

Bacillus septicus insectorum Krassilstschik. (Memoires de la Soc. Zool. de France, *6*, 1893, 250.) From cockchafer larvae (*Melolontha melolontha*).

Bacillus serrulatus Stührk. (Cent. f. Bakt., II Abt., *93*, 1935, 193.) Only moderate growth on Ca n-butyrate agar. One culture isolated from Cuban soil.

Bacillus sesami Malkoff. (Cent. f. Bakt., II Abt., *16*, 1906, 665.) Pathogenic on sesame (*Sesamum*).

Bacillus siccus Chester. (Bacillus No. 25, Conn, Storrs Agr. Exp. Sta. Rept., 1893, 63; Chester, Man. Determ. Bact., 1901, 284.) From milk.

Bacillus similis Schroeter. (Bacillus II, Bienstock, Ztschr. f. klin. Med., *8*, 1884, Heft 1 and 2; Schroeter, in Cohn, Kryptog.-Flora v. Schlesien, *3*, 1, 1886, 160; *Bacillus coprocinus* Trevisan, I generi e le specie delle Batteriacee, Milan, 1889, 15; *Bacillus faecalis* No. II, Kruse, in Flügge, Die Mikroorganismen, 3 Aufl., *2*, 1896, 215; *Bacterium simile* Chester, Man. Determ. Bact., 1901, 197.) From feces.

Bacillus similis Eckstein. (Arch. f. Forst- u. Jagdwesen, *26*, 1894, 11.) From infected larvae of the nun moth (*Lymantria monacha*), etc.

Bacillus similityphosus Migula. (Typhusähnlicher Bacillus, Maschek, Bakt. Untersuch. d. Leitmeritz. Trinkwässer, Leitmeritz, 1887; Migula, Syst. d. Bakt., *2*, 1900, 730.) From water.

Bacillus sinapivagus Kossowicz. (Cent. f. Bakt., II Abt., *23*, 1909, 241.) From pickles.

Bacillus sombrosus Kern. (Arb. bakt. Inst. Karlsruhe, *1*, Heft 4, 1896, 429.) From the stomach of a bird.

Bacillus sorghi Burrill. (The Microscope, *7*, 1887, 321; Proc. Amer. Soc. Microscopists, 1888, 193; *Bacterium sorghi* Chester, Delaware Agr. Exp. Sta. Ann. Rept., *9*, 1897, 127; Elliott and Smith, Jour. Agr. Res., *38*, 1928, 1.) Reported to cause a disease of sorghum (*Holcus sorghum*).

Bacillus sotto Paillot. (Sotto-Bacillus, Ischivata, quoted from Aoki and Chigasaki, Mitteil. d. Med. Fakul. d. k. Univ. z. Tokyo, *13*, 1915, 419 and *14*, 1915, 59; *Bacterium sotto* Metalnikov and Chorine, Internat. Corn Borer Invest., Sci. Repts., *1*, 1928, 56; Paillot, *ibid.*, *1*, 1928, 77–106.) From silkworms (*Bombyx mori*). Sotto is Japanese for "plötzlich hinfallen".

Bacillus spatiosus Saito. (Jour. Coll. Sci., Imp. Univ., Tokyo, *23*, Art. 15, 1908, 56.) Isolated once from garden air.

Bacillus spermatozoides Eckstein. (Ztschr. f. Forst- u. Jagdwesen, *26*, 1894, 13.) From dead moths (*Hyponomeuta evonymella*).

Bacillus sphaerosporus Beijerinck. (Cent. f. Bakt., II Abt., *25*, 1909, 45.) This organism has round terminal spores and produces nitrous oxide from nitrates. From garden soil.

Bacillus sphaerosporus calco-aceticus Beijerinck (*loc. cit.*, 46). A variety of the above having spherical to ellipsoidal spores.

Bacillus spinosporus Soriano. (Thesis, Univ. Buenos Aires, 1935, 562.) Spores spinate like some strains of *Bacillus polymyxa*. No gas formed. One strain isolated from soil.

Bacillus spiralis Migula. (Syst. d. Bakt., *2*, 1900, 624.) From water.

Bacillus spirogyra Dobell. (Quart. Jour. Micro. Sci., *53*, 1909, 579 and *56*, 1911, 434.) From large intestine of frog (*Rana temporaria*) and toad (*Bufo vulgaris*).

Bacillus spongiosus Aderhold and Ruhland. (Cent. f. Bakt., II Abt., *15*, 1905, 376.) Found in the gum masses discharged by cherry trees.

Bacillus sporonema Schaudinn. (Arch. f. Protistenkunde, *2*, 1903, 421.) From sea water.

Bacillus spurius Grohmann. (Morphologisch-biologische Beiträge zur Kenntnis der Wasserstoffbakterien, Inaug. Diss., Univ. Leipzig, 1923; Cent. f. Bakt., II Abt., *61*, 1924, 267; Ruhland and Grohmann, Jahrb. wissensch. Botanik, *63*, 1924, 321.) Oxidizes hydrogen in the presence of oxygen to form water. Presumably widely distributed in soil.

Bacillus sputi Chester. (Bacillus No. 6, Pansini, Arch. f. path. Anat., *122*, 1890, 442; Chester, Man. Determ. Bact., 1901, 280.) From sputum.

Bacillus squamiformis Saito. (Jour. Coll Sci., Imp. Univ., Tokyo, *23*, Art. 15, 1908, 54.) Isolated 9 times from garden soil.

Bacillus stellaris Saito. (Jour. Coll. Sci., Imp. Univ., Tokyo, *23*, Art. 15, 1908, 52.) Isolated 6 times from garden air.

Bacillus stellatus Zimmermann. (Zimmermann, Bakt. unserer Trink- u. Nutzwässer, II Reihe, 1894, 14; not *Bacillus stellatus* Chester, Man. Determ. Bact., 1901, 274; not *Bacillus stellatus* Vincent, Ann. Inst. Past., *21*, 1907, 62.) From water.

Bacillus streptoformis Migula. (Salpeter zerstörenden Bacillus, Schirokikh, Cent. f. Bakt., II Abt., *2*, 1896, 204; Migula, Syst. d. Bakt., *2*, 1900, 682; *Bacillus schirokikhi* Chester, Man. Determ. Bact., 1901, 252; *Bacillus denitrificans* Chester, *ibid.*, 274.) From horse feces. Utilizes potassium nitrate.

Bacillus suaveolens Sclavo and Gosio. (Quoted from Omeliansky, Jour. Bact., *8*, 1923, 398.) No source given.

Bacillus subcuticularis Migula. (*Bacillus cuticularis albus* Tataroff, Inaug. Diss., Dorpat, 1891, 24; Migula, Syst. d. Bakt., *2*, 1900, 623; *Bacillus cuticularis* Chester, Man. Determ. Bact., 1901, 285.) From water.

Bacillus sublanatus Wright. (Mem. Nat. Acad. Sci., *7*, 1895, 455.) From water.

Bacillus sublustris Schieblich. (Cent. f. Bakt., II Abt., *58*, 1923, 206.) Commonly isolated from green and fermenting fodders.

Bacillus submarinus ZoBell and Upham. (Bull. Scripps Inst. of Oceanography, Univ. Calif., *5*, 1944, 267.) Central ovate spores. From marine bottom deposits.

Bacillus (*Streptobacter*) *subtiliformis* Schroeter. (*Bacillus I*, Bienstock, Ztschr. f. klin. Med., *8*, Heft 1 and 2, 1884; Schroeter, in Cohn, Kryptog.-Flora v. Schlesien, *3*, 1, 1886, 160; *Bacillus mesenthericus* (sic) Trevisan, I generi e le specie delle Batteriacee, Milan, 1889, 15; not *Bacillus mesentericus* Trevisan, *ibid.*, 19; *Bacillus subtilis simulans I*, Eisenberg, Bakt. Diag., 3 Aufl., 1891, 189; *Bacillus faecalis* No. I, Kruse, in Flügge, Die Mikroorganismen, 3 Aufl., *2*, 1896, 215; *Bacterium subtile* Migula, Syst. d. Bakt., *2*, 1900, 292; *Bacterium subtiliforme* Chester, Man. Determ. Bact., 1901, 197.) From feces.

Bacillus succinicus Fitz. (Quoted from DeToni and Trevisan, in Saccardo, Sylloge Fungorum, *8*, 1889, 966.) From infusions.

Bacillus suffuscus Grohmann. (Morphologisch-biologische Beiträge zur Kenntnis der Wasserstoffbakterien, Inaug. Diss., Univ. Leipzig, 1923; Cent. f. Bakt., II Abt., *61*, 1924, 267; Ruhland and Grohmann, Jahrb. wissensch. Botanik, *63*, 1924, 321.) Oxidizes hydrogen in the presence of oxygen to form water. Presumably widely distributed in soil.

Bacillus supraresistans Stührk. (Cent. f. Bakt., II Abt., *93*, 1935, 185.) Very good growth on Ca n-butyrate agar. One culture isolated from soil in Germany.

Bacillus surgeri Dornic and Daire. (Bull. mensuel de l'Office de renseignements agricoles, *6*, 1907; abst. in Rev. Gén. du Lait., *6*, 1907, 164.) Spores not observed but author stated that they were probably present because this species could withstand 85°C for 5 minutes. From whey.

Bacillus tabaci III, Koning. (Tijdschr. voor toegepaste scheikunde en hygiene. Deel 1, 1897. See Behrens, Mykologie der Tabakfabrikation, in Lafar, Handbuch der techn. Mykologie, *5*, 1905, 11.) Thermophilic. Probably from soil.

Bacillus tardivus Stührk. (Cent. f. Bakt., II Abt., *93*, 1935, 177.) Very slight growth on Ca n-butyrate agar. One culture isolated from garden soil of Germany.

Bacillus technicus Morikawa and Prescott. (Jour. Bact., *13*, 1927, 58; also see Morikawa, Bull. Agr. Chem. Soc. Japan, *3*, 1927, 28.) Produces butyl and isopropyl alcohols. Source not given.

Bacillus tenax Eckstein. (Ztschr. f. Forst- u. Jagdwesen, *26*, 1894, 14.) From larvae of the nun moth (*Lymantria monacha*).

Bacillus tenuis non-liquefaciens Choukévitch. (Ann. Inst. Past., *25*, 1911, 352.) From large intestine of horse.

Bacillus terminalis Migula. (Bacillus No. XII, Flügge, Ztschr. f. Hyg., *17*, 1894, 296; *Bacillus lactis* No. XII, Kruse, in Flügge, Die Mikroorganismen, 3 Aufl., *2*, 1896, 269; Migula, Syst. d. Bakt., *2*, 1900, 578; *Bacillus lacteus* Chester, Man. Determ. Bact., 1901, 291.) From milk. A duplicate of *Bacterium sempervivum* Migula.

Bacillus terminalis var. *thermophilus* Prickett. (N. Y. Agr. Exp. Sta. Tech. Bull. 147, 1928, 44.) Produces a brown water soluble pigment on agar; optimum temperature 55°C to 65°C. Fourteen strains from raw and pasteurized milk, milk powder, and skin of a cow.

Bacillus terrestris Werner. (Cent. f. Bakt., II Abt., *87*, 1933, 461.) Weak growth on Ca n-butyrate agar. Two strains isolated from soils of Germany.

Bacillus tetanoides Saito. (Jour. Coll. Sci., Imp. Univ., Tokyo, *23*, Art. 15, 1908, 49.) Isolated once from garden air.

Bacillus thalassokoites ZoBell and Upham. (Bull. Scripps Inst. of Oceanography, Univ. Calif., *5*, 1944, 268.) Central spores. From marine bottom deposits.

Bacillus theae Hori and Bokura. (Jour. Plant Protection, Tokyo, *2*, 1915, 1.) Pathogenic for tea (*Thea sinensis*).

Bacillus thermoabundans Beaver. (Dissertation, Ohio State University, Columbus, 1932, 31.) Thermophilic, subterminal spores. Growth at 55°C, less growth at 37°C. From malted milk powder.

Bacillus thermoacetigenitus Beaver, *loc. cit.*, 25. Thermophilic, central spores. No growth at 37°C. From vinegar.

Bacillus thermoacidificans Renco. (Ann. Microbiol., *2*, 1942, 000.) From Grana cheese whey. This is stated by Gorini (R. Ist. Lombardo Sci. e. Lett., Rend., *76*, 7ᵉ della Ser. 3, 1942, 3) to be the same as *Bacillus lactis termophilus* Gorini.

Bacillus thermoactivus Beaver, *loc. cit.*, 27. Thermophilic, central spores. No growth at 37°C. From home-canned beets.

Bacillus thermoannulatus Beaver, *loc. cit.*, 17. Thermophilic, subterminal spores. No growth at 37°C. From commercially canned tomatoes.

Bacillus thermoaquatilis Beaver, *loc. cit.*, 18. Thermophilic, subterminal spores. No growth at 37°C. From a warm spring at Springfield, Ohio.

Bacillus thermoarborescens Beaver, *loc. cit.*, 30. Thermophilic, sub-terminal to central spores. Growth at 55°C, less growth at 37°C. From candy.

Bacillus thermobutyrosus Beaver, *loc. cit.*, 15. Thermophilic, subterminal spores. No growth at 37°C. From commercially canned tomatoes.

Bacillus thermocompactus Beaver, *loc. ict.*, 20. Thermophilic, subterminal spores. No growth at 37°C. From red grapes stored in sawdust.

Bacillus thermodactylogenitus Beaver, *loc. cit.*, 28. Thermophilic, central to subterminal spores. Growth at 37°C and 55°C. From commercially packed dates.

Bacillus thermoeffervescens Beaver, *loc. cit.*, 23. Thermophilic, central spores. No growth at 37°C. From commercially canned peas.

Bacillus thermofaecalis Beaver, *loc. cit.*, 30. Thermophilic, subterminal spores. Growth at 55°C. From feces of robin.

Bacillus thermofibrincolus Itano and Arakawa. (Ber. d. Ohara Inst. f. landwirsch. Forschungen, Japan, *4*, 1929, 265.) Thermophilic; decomposes cellulose. From soil containing decomposed leaves.

Bacillus thermofiliformis Beaver, *loc. cit.*, 22. Thermophilic, subterminal spores. No growth at 37°C. From commercially canned peas.

Bacillus thermograni Beaver, *loc. cit.*, 16. Thermophilic, subterminal spores. No growth at 37°C. From commercially canned corn.

Bacillus thermolongus Beaver, *loc. cit.*, 19. Thermophilic, subterminal spores. No growth at 37°C. From commercially canned tomatoes.

Bacillus thermolubricans Beaver, *loc. cit.*, 26. Thermophilic, central spores. No growth at 37°C. From lubricating oil.

Bacillus thermononodorus Beaver, *loc. cit.*, 26. Thermophilic, central spores. No growth at 37°C. From tap water.

Bacillus thermonubilosus Beaver, *loc. cit.*, 19. Thermophilic, subterminal spores. No growth at 37°C. From soil, Yellow Springs, Ohio.

Bacillus thermoodoratus Beaver, *loc. cit.*, 29. Thermophilic, central spores. Growth at 55°, less growth at 37°C. From spoiled gelatin.

Bacillus thermopellitus Beaver, *loc. cit.*, 22. Thermophilic, central spores. No growth at 37°C. From old sour milk.

Bacillus thermophilus Miquel. (Miquel, Ann. d. Micrtypes., *1*, 1888, 4; *Bacillus thermophilus miquelii* Kruse, in Flügge, Die Mikroorganismen, 3 Aufl., *2*, 1896, 269; *Bacterium termophilum* (sic) Migula, Syst. d. Bakt., *2*, 1900, 342; *Bacterium miquelii* Chester, Man. Determ. Bact., 1901, 186.) From the

intestine, water and soil. Thermophilic. No growth below 40°C.

Bacillus thermophilus sojae Rokusho and Fukutome. (Jour. Agr. Chem. Soc., Japan, *13*, 1937, 1235.) From spontaneously heating soy-bean cake.

Bacillus thermosuavis Beaver, *loc. cit.*, 24. Thermophilic, central spores. No growth at 37°C. From commercially canned mincemeat.

Bacillus thermotenax Beaver, *loc. cit.*, 28. Thermophilic, subterminal spores. Growth at 37°C and 55°C. From ground horseradish.

Bacillus thermourinalis Beaver, *loc. cit.*, *16*. Thermophilic, subterminal spores. No growth at 37°C. From human urine.

Bacillus thermoviscidus Beaver, *loc. cit.*, 21. Thermophilic, subterminal spores. No growth at 37°C. From fresh pig ovary.

Bacillus thoracis Howard. (Gleanings in Bee Culture, *28*, 1900, 124.) From black brood of the honey bee (*Apis mellifera*).

Bacillus tracheitis sive *graphitosis* Krassilstschik. (Memoires de la Soc. Zool. de France, *6*, 1893, 250.) From diseased larvae of the cockchafer (*Melolontha melolontha*).

Bacillus tricomii Trevisan. (Bacillo della gangraena senilis, Tricomi, Riv. internaz. di Med. e Chir., *3*, 1886, 73; Trevisan, I generi e le specie delle Batteriacee, 1889, 13; *Bacterium tricomii* Migula, Syst. d. Bakt., *2*, 1900, 310.) From a case of senile gangrene.

Bacillus trifolii Voglino. (Ann. R. Accad. Agr. Torino, *39*, 1896, 85.) Pathogenic for clover (*Trifolium pratense*, *T. repens*, *T. resupinatum*).

Bacillus tritus Batchelor. (Jour. Bact., *4*, 1919, 29.) One culture from feces.

Bacillus tuberis von Wahl. (Cent. f. Bakt., II Abt., *16*, 1906, 503.) From cooked truffles (*Tuber oestivum*).

Bacillus tuberosus Weiss. (Arb. bakt. Inst. Karlsruhe, *2*, Heft 3, 1902, 248.) From fermenting beets.

Bacillus tubifex Dale. (Annals of Bot., *26*, 1912, 133.) Reported to cause a leaf disease of potato (*Solanum tuberosum*) and tomato (*Lycopersicum esculentum*).

Bacillus turgidus (Duclaux) Trevisan. (*Tyrothrix turgidus* Duclaux, Ann. Inst. Nat. Agron., *4*, 1882, 23; Trevisan, I generi e le specie delle Batteriacee, 1889, 16.) From milk.

Bacillus tympani-cuniculi Morcos. (Jour. Bact., *23*, 1932, 454.) Causes tympanitis in young rabbits.

Bacillus ubicuitarius Soriano. (Estudio sistematico de algunas bacterias esporuladas aerobias, Thesis, Univ. Buenos Aires, 1935, 569.) Four cultures isolated from soil.

Bacillus ulna Cohn. (Cohn, Beitr. z. Biol. d. Pflanz., *1*, Heft 2, 1872, 177; also see Prazmowski, Untersuch. ü. d. Entwickelungsges. u. Fermentwirk. einiger Bakterienarten, Leipzig, 1880, 20.) Found once in an infusion of cooked egg-white.

Bacillus undulatus den Dooren de Jong. (Bull. Assoc. Diplômés de Microbiol. Nancy, No. 26–27, 1946, 12.) From soil.

Bacillus uvaeformis Kern. (Arb. bakt. Inst. Karlsruhe, *1*, Heft 4, 1896, 415.) From the stomachs and intestines of birds.

Bacillus vaculatus Ravenel. (Mem. Nat. Acad. Sci., *8*, 1896, 31.) From soil.

Bacillus validus Heigener. (Cent. f. Bakt., II Abt., *93*, 1935, 97.) Four cultures isolated from soil from Germany, Cuba, and Egypt.

Bacillus valinovorans Heigener. (Cent. f. Bakt., II Abt., *93*, 1935, 104.) Good growth on valine agar. Five strains isolated from soils from Egypt, Germany, Italy, and Palestine.

Bacillus varians Saito. (Jour. Coll. Sci., Imp. Univ., Tokyo, *23*, Art. 15, 1908, 50.) Isolated 11 times from garden air.

Bacillus ventricosus Heigener. (Cent.

f. Bakt., II Abt., *93*, 1935, 102; not *Bacillus ventricosus* Weiss, Arb. bakt. Inst. Karlsruhe, *2*, 1898, 233.) One culture isolated from soil from Italy.

Bacillus ventriculus Koch. (Botan. Zeitung, *46*, 1888, 341.) From slices of carrot exposed to the air. Formed two spores in a spindle-shaped sporangium.

Bacillus vernicosus Zimmermann. (Bakt. unserer Trink- u. Nutzwässer, Chemnitz, II Reihe, 1894, 46; not *Bacillus vernicosus* Migula, Syst. d. Bakt., *2*, 1900, 781.) From waste water.

Bacillus verticillatus Ravenel. (Ravenel, Mem. Nat. Acad. Sci., *8*, 1896, 13; *Bacterium verticillatum* Chester, Man. Determ. Bact., 1901, 192.) From soil.

Bacillus vesicae Migula. (*Bacillus septicus vesicae* Clado, quoted from Eisenberg, Bakt. Diag., 3 Aufl., 1891, 341; Migula, Syst. d. Bakt., *2*, 1900, 620.) From urine in a case of cystitis. Probably is *Bacillus cladoi* Trevisan.

Bacillus villosus Zimmermann. (Bakt. unserer Trink- u. Nutzwässer, Chemnitz, II Reihe, 1894, 38; not *Bacillus villosus* Keck, Inaug. Diss., Dorpat, 1890, 47.) From water.

Bacillus violaceus Eisenberg. (Bakt. Diag., 2 Aufl., 1888, 8; not *Bacillus violaceus* Schroeter, Kryptogamen-Flora von Schlesien, *3*, 1886, 157; not *Bacillus violaceus* Frankland and Frankland, Ztschr. f. Hyg., *6*, 1888, 394.) Said to produce central spores. From water.

Bacillus viridi-glaucescens Sack. (Cent. f. Bakt., II Abt., *65*, 1925, 113.) From several kinds of soil.

Bacillus viridiluteus Pagliani et al. (Grüngelber, nicht verflüssiger Bacillus, Eisenberg, Bakt. Diag., 1 Aufl., 1886, Tab. 6; Pagliani, Maggiora and Fratini, Soc. ital. d'igiene, 1887, 586, see Trevisan, I generi e le specie delle Batteriacee, 1889, 19). From water.

Bacillus viscosus bruxellensis van Laer. (Cent. f. Bakt., II Abt., *23*, 1909, 159.) From beer wort.

Bacillus viticola Burgwitz. (*Bacillus vitis* Merjanian and Kovaleva, Prog. Agric. et Vitic., *95*, 1930, 594 and *96*, 1931, 17; not *Bacillus vitis* Montemartini, Rev. Patol. Veg., *6*, 1913, 175; Burgwitz, Phytopath. Bacteria, Leningrad, 1935, 37.) Pathogenic for the grape vine.

Bacillus vitreus Migula. (No. 11, Lembke, Arch. f. Hyg., *26*, 1896, 306; Migula, Syst. d. Bakt., *2*, 1900, 569.) From the intestines of infants.

Bacillus vogelii Migula. (Roter Kartoffelbacillus, Vogel, Ztschr. f. Hyg., *26*, 1897, 404; Migula, Syst. d. Bakt., *2*, 1900, 556; *Bacillus viscosus* Chester, Man. Determ. Bact., 1901, 286; not *Bacillus viscosus* Frankland and Frankland, Ztschr. f. Hyg., *6*, 1889, 391.) From stringy bread.

Bacillus watzmannii Werner. (Cent. f. Bakt., II Abt., *87*, 1933, 462.) Weak growth on Ca n-butyrate agar. One culture isolated from soil of Germany.

Bacillus weigmanni Migula. (Bakterie II, Weigmann and Zirn, Cent. f. Bakt., *15*, 1894, 465; Migula, Syst. d. Bakt., *2*, 1900, 693.) From soapy milk.

Bacillus xylanicus Patrick and Werkman. (Iowa State Coll. Jour. Sci., *7*, 1933, 415.) Ferments xylan. One culture isolated from decayed apple wood.

Bacillus xylophagus Patrick and Werkman. (Iowa State Coll. Jour. Sci., *7*, 1933, 414.) Ferments xylan. One culture isolated from decayed apple wood.

Bacillus zirnii Migula. (Bakterie III, Weigmann and Zirn, Cent. f. Bakt., *15*, 1894, 466; Migula, Syst. d. Bakt., *2*, 1900, 693.) From soapy milk.

Bacterium adametzii Migula. (Bacillus No. XIV, Adametz, Landwirtsch. Jahrb., *18*, 1889, 246; Migula, Syst. d. Bakt., *2*, 1900, 338; *Bacterium rugosum* Chester, Man. Determ. Bact., 1901, 194.) From cheese.

Bacterium aloes Passalacqua. (Rev. Pat. Veg., *19*, 1929, 110.) From diseased aloes.

Bacterium angulans Burchard. (Inaug. Diss., 1897; Arb. bakt. Inst. Karlsruhe, *2*, Heft 1, 1902, 43.) From water.

Bacterium aqueum Migula. (*Bacillus thermophilus VIII*, Rabinowitsch, Ztschr. f. Hyg., *20*, 1895, 160; Migula,

Syst. d. Bakt., *2*, 1900, 345; *Bacterium thermophilum VIII*, Chester, Man. Determ. Bact., 1901, 186.) From feces and corn.

Bacterium articulatum Kern. (Arb. bakt. Inst. Karlsruhe, *1*, Heft 4, 1897, 445.) From the stomach and intestines of birds.

Bacterium asparagi von Wahl. (Von Wahl, Cent. f. Bakt., II Abt., *16*, 1906, 498; *Bacillus asparagi* Lehmann and Neumann, Bakt. Diag., 4 Aufl., *2*, 1907, 436.) From boiled asparagus.

Bacterium brachysporum Burchard. (Inaug. Diss., 1897; Arb. bakt. Inst. Karlsruhe, *2*, Heft 1, 1902, 20.) From bakery bread.

Bacterium canadensis Chorine. (Internat. Corn Borer Invest., Sci. Rpts., *2*, 1929, 39; also Ann. Inst. Past., *43*, 1929, 1658; *Bac. canadensis* Chorine and Metalnikov, Ann. Inst. Past., *43*, 1929, 1392; also Paillot, L'infection chez les insectes, 1933, 134 where *Bac.* equals *Bacterium*, see index p. 522; *Bacillus canadensis* Steinhaus, Bacteria Associated Extracellularly with Insects, Minneapolis, 1942, 50.) In its general characters said to resemble *Bacillus megatherium* and other bacteria isolated from insects (*Bacillus thuringiensis*, *Bacillus hoplosternus*, etc.). Pathogenic for larvae of *Pyrausta nubilalis*, *Galleria mellonella*, and *Ephestia kuhniella*. From diseased larvae of the corn borer.

Bacterium cattleyae Pavarino. (Atti R. Accad. Naz. Lincei Rend. Cl. Sci. Fis., Mat. e. Nat., *20*, 1911, 233.) From diseased orchids.

Bacterium cazaubon Metalnikov. (Compt. rend. Soc. Biol., Paris, *105*, 1930, 536; two varieties, *Bacterium cazaubon* I and II, are recognized by Metalnikov, Ermolaev and Schobaltzyn, Internat. Corn Borer Invest., Sci. Repts., *3*, 1930, 30 and Ann. Inst. Past., *46*, 1931, 469.) From diseased corn borer larvae (*Pyrausta nubilalis* Hb.).

Bacterium christiei Chorine. (Internat. Corn Borer Invest., Sci. Rpts., *2*, 1929, 46; also Ann. Inst. Past., *43*, 1929, 1666.) According to the author, this closely resembles *Bacterium ontarioni*. Several strains isolated from diseased corn borers.

Bacterium colomatii Chester. (Colomatii, Breslauer arztliche Ztschr., 1883, No. 4; Chester, Man. Determ. Bact., 1901, 186.) From xerotic masses in conjunctivitis.

Bacterium deliense Swellengrebel. (Archiv f. Protist., *31*, 1913, 277.) Observed in stained smears from the spleen of diseased cattle but not isolated. Two spores may form in a single cell if division is delayed.

Bacterium ephestiae No. 1 and No. 2 Metalnikov and Chorine. (Ann. Inst. Past., *43*, 1929, 1394.) Not pathogenic for corn borer although the size of the larvae was reduced. Later, Ellinger and Chorine (Internat. Corn Borer Investigations, Sci. Rpts., *3*, 1930, 37) identified these as strains of *Bacillus thuringiensis*. From diseased larvae of *Ephestia kuehniella*.

Bacterium filiforme Henrici. (Henrici, Arb. bakt. Inst. Karlsruhe, *1*, Heft 1, 1894, 41; not *Bacterium filiforme* Migula, Syst. d. Bakt., *2*, 1900, 296; *Bacterium subfiliforme* Migula, *ibid.*, 297.) From Swiss cheese.

Bacterium galleriae No. 1, Chorine. (Bâtonnet mince, Metalnikov, Compt. rend. Acad. Sci., Paris, *175*, 1922, 69; Chorine, Ann. Inst. Past., *41*, 1927, 1115.) From diseased larvae of the bee moth (*Galleria mellonella*).

Bacterium galleriae Chorine. (Plus grand bâtonnet, Metalnikov, Compt. rend. Acad. Sci., Paris, *175*, 1922, 70; Chorine, Compt. rend. Soc. Biol., Paris, *95*, 1926, 200; *Bacterium galleriae No. 2*, Chorine, Ann. Past. Inst., *41*, 1927, 1117.) From diseased larvae of the bee moth (*Galleria mellonella*). Resembles *Bacillus megatherium*. Pathogenic for the corn borer (Internat. Corn Borer Invest., Sci. Repts., *1*, 1927, 46).

Bacterium galleriae No. 3, Chorine. (Ann. Inst. Past., *41*, 1927, 1118.) From diseased larvae of the bee moth (*Galleriae mellonella*). Resembles *Bacillus subtilis* and *Bacillus mesentericus*.

Bacterium giganteum Kern. (Arb. bakt. Inst. Karlsruhe, *1*, Heft 4, 1896, 453.) From the stomach and intestines of birds.

Bacterium glaucescens Migula. (*Bacillus thermophilus VI*, Rabinowitsch, Ztschr. f. Hyg., *20*, 1895, 158; Migula, Syst. d. Bakt., *2*, 1900, 344; *Bacterium thermophilum VI*, Chester, Man. Determ. Bact., 1901, 185.) From feces.

Bacterium glutinosum Kern. (Arb. bakt. Inst. Karlsruhe, *1*, Heft 4, 1896, 441.) From the stomach of a dove.

Bacterium ilidzense Migula. (*Bacillus ilidzensis capsulatus* Karlinski, Hygienische Rundschau, *5*, 1895, 688; Migula, Syst. d. Bakt., *2*, 1900, 340.) From the water of a hot spring. Thermophilic.

Bacterium implectans Burchard. (Inaug. Diss., 1897; Arb. bakt. Inst. Karlsruhe, *2*, Heft 1, 1898, 29.) From drinking water.

Bacterium insulosum Wilhelmy. (Arb. bakt. Inst. Karlsruhe, *3*, 1903, 16.) From meat extract.

Bacterium insulum Weiss. (Arb. bakt. Inst. Karlsruhe, *2*, Heft 3, 1902, 252.) From fermenting malt.

Bacterium intactum Migula. (*Bacillus thermophilus V*, Rabinowitsch, Ztschr. f. Hyg., *20*, 1895, 158; Migula, Syst. d. Bakt., *2*, 1900, 344; *Bacterium thermophilum V*, Chester, Man. Determ. Bact., 1901, 185.) From feces and corn.

Bacterium iris Migula. (Irisierender Bacillus, Tataroff, Inaug. Diss., Dorpat, 1891, 57; Migula, Syst. d. Bakt., *2*, 1900, 313; not *Bacterium iris* Chester, Ann. Rept. Del. Col. Agr. Exp. Sta., *9*, 1897, 125.) From water.

Bacterium italicum No. 1 and No. 2, Metalnikov, Ermolaev and Skobaltzyn. (Ann. Inst. Past., *46*, 1931, 470; No. 2 is also described in Internat. Corn Borer Invest. Sci. Repts., *3*, 1930, 30.) From larvae of the corn borer (*Pyrausta nubilalis*).

Bacterium longum Kern. (Kern, Arb. bakt. Inst. Karlsruhe, *1*, Heft 4, 1894, 391; *Bacterium squamosum longum* Kern, *ibid.*, 458; *Bacillus squamosus longus* Chorine, Ann. Inst. Past., *41*, 1927, 1114.) From the intestines of a dove (*Columba oenas*).

Bacterium lunula Dobell. (Quart. Jour. Micro. Sci., *53*, 1909, 579.) From rectum of the toad (*Bufo vulgaris*). Resembles *Bacterium binucleatum* Swellengrebel.

Bacterium lydiae Migula. (*Bacillus thermophilus I*, Rabinowitsch, Ztschr. f. Hyg., *20*, 1895, 156; Migula, Syst. d. Bakt., *2*, 1900, 343; *Bacterium thermophilum I*, Chester, Man. Determ. Bact., 1901, 185.) Widely distributed in soil, snow, feces, corn.

Bacterium mansfieldii Chester. (Bacillus No. 18, Conn, Storrs Agr. Expt. Sta., 1893, 51; Chester, Man. Determ. Bact., 1901, 197.) From milk.

Bacterium markusfeldii Chester. (Bacillus der trichorrhexis nodosa, Markusfeld, Cent. f. Bakt., I Abt., *21*, 1897, 230; Chester, Man. Determ. Bact., 1901, 192.) Associated with the disease, trichorrhexis nodosa.

Bacterium mesentericum Migula. (*Bacillus mesentericus panis viscosi I*, Vogel, Ztschr. f. Hyg., *26*, 1897, 404; Migula, Syst. d. Bakt., *2*, 1900, 314; *Bacterium panis* Chester, Man. Determ. Bact., 1901, 196.) From stringy bread dough.

Bacterium mesenteroides Migula. (Bacillus No. XVII, Adametz, Landw. Jahrb., *18*, 1889, 249; Migula, Syst. d. Bakt., *2*, 1900, 312; *Bacterium viscosum* Chester, Man. Determ. Bact., 1901, 194.) From cheese.

Bacterium modestum Bersteyn. (Arb. bakt. Inst. Karlsruhe, *3*, 1903, 95.) From soil.

Bacterium monstrosum Henrici. (Arb. bakt. Inst. Karlsruhe, *1*, Heft 1, 1894, 47.) From Swiss cheese.

Bacterium nephritidis Migula. (*Bacillus nephritidis interstitialis* Letzerich, Ztschr. f. klin. Med., *13*, 188–, 33; Migula, Syst. d. Bakt., *2*, 1900, 310; not *Bacterium nephritidis* Chester, Man. Determ. Bact., 1901, 145.) From urine in cases of nephritis.

Bacterium ochraceum Migula. (*Bacillus viscosus ochraceus* Freund, Martin

Inaug. Diss., Erlangen, 1893, 37; Migula, Syst. d. Bakt., *2*, 1900, 333.) From the oral cavity.

Bacterium olivae Montemartini. (Atti Inst. Bot. Pavia Univ., 2 ser., *14*, 1914, 154.) From diseased olive branches.

Bacterium paludosum McBeth. (Soil Sci., *1*, 1916, 463.) Filter paper reduced to a white pulp-mass. From two soils in California.

Bacterium perittomaticum Burchard. (Arb. bakt. Inst. Karlsruhe, *2*, 1898, 11.) Similar to or identical with *Bacillus ruminatus* (Gottheil, Cent. f. Bakt., II Abt., *7*, 1901, 485). From soil.

Bacterium pituitans Burchard. (Inaug. Diss., 1897; Arb. bakt. Inst. Karlsruhe, *2*, Heft 1, 1898, 8.) From a brown concretion in a cooked egg.

Bacterium plicativum Weiss. (Weiss, Arb. bakt. Inst. Karlsruhe, *2*, Heft 3, 1902, 223; not *Bacterium plicativum* Migula, Syst. d. Bakt., *2*, 1900, v and 453.) From fermenting beets and malt.

Bacterium plicatum Henrici. (Henrici, Arb. bakt. Inst. Karlsruhe, *1*, Heft 1, 1894, 49; not *Bacterium plicatum* Chester, Man. Determ. Bact., 1901, 166.) From brick cheese.

Bacterium pseudaceti Migula. (Bacillus No. XV, Adametz, Landw. Jahrb., *18*, 1889, 247; Migula, Syst. d. Bakt., *2*, 1900, 320; *Bacterium turgidum* Chester, Man. Determ. Bact., 1901, 195.) From cheese. Characteristic involution forms very similar to those of *Bacillus aceti* Hansen.

Bacterium pseudomycoides Migula. (Migula, Syst. d. Bakt., *2*, 1900, 486; *Bacillus pseudomycoides roseus* Nepveux, Thèse, Fac. Pharm., Nancy, 1920, 112.) From soil.

Bacterium pseudovermiculosum Saito. (Jour. Coll. Sci., Imp. Univ., Tokyo, *23*, Art. 15, 1908, 62.) Isolated twice from garden air.

Bacterium pyrenei No. 1, No. 2 and No. 3, Metalnikov, Ermolaev and Skobaltzyn. (Internat. Corn Borer Invest., *3*, 1930, 28 and Ann. Inst. Past., *46*, 1931, 467, 468 and 469 respectively; presumably the same as *Bacillus pirenei* Pospelov, Lenin Acad. Agr. Sci. (U.S.S.R.), Ann. Rept. 1936, 318–321.) No. 1 from diseased larvae of the corn borer (*Pyrausta nubilalis*) that had become black after death; No. 2 from larvae that had become brown; and No. 3 from larvae that had become pinkish-brown.

Bacterium radiatum Kern. (Kern, Arb. bakt. Inst. Karlsruhe, *1*, Heft 4, 1896, 438; *Bacterium barbatum* Migula, Syst. d. Bakt., *2*, 1900, 317.) From the stomach of a finch.

Bacterium rusticum Kern. (Arb. bakt. Inst. Karlsruhe, *1*, Heft 4, 1896, 440.) From the stomach of a sparrow.

Bacterium sempervivum Migula. (No. XII, Flügge, Ztschr. f. Hyg., *17*, 1894, 296; *Bacillus lactis* No. XII, Kruse, in Flügge, Die Mikroorganismen, 3 Aufl., *2*, 1896, 269; Migula, Syst. d. Bakt., *2*, 1900, 321.) From milk.

Bacterium serratum Kern. (Arb. bakt. Inst. Karlsruhe, *1*, Heft 4, 1896, 451.) From the intestine of a dove.

Bacterium sewerini Migula. (Sewerin, Cent. f. Bakt., II Abt., *3*, 1897, 709; Migula, Syst. d. Bakt., *2*, 1900, 330.) From manure.

Bacterium spissum Kern. (Arb. bakt. Inst. Karlsruhe, *1*, Heft 4, 1896, 446.) From the intestine of a bird.

Bacterium sputicola Migula. (Bacillus No. 4, Pansini, Arch. f. path. Anat., *122*, 1890, 440; Migula, Syst. d. Bakt., *2*, 1900, 306; *Bacterium sputi* Chester, Man. Determ. Bact., 1901, 190.) From sputum.

Bacterium streptococciforme Migula. (*Bacillus thermophilus III*, Rabinowitsch, Ztschr. f. Hyg., *20*, 1895, 156; Migula, Syst. d. Bakt., *2*, 1900, 343; *Bacterium thermophilum III*, Chester, Man. Determ. Bact., 1901, 185.) From soil, feces, corn.

Bacterium subdenticulatum Migula. (*Bacillus thermophilus VII*, Rabinowitsch, Ztschr. f. Hyg., *20*, 1895, 158; Migula, Syst. d. Bakt., *2*, 1900, 345; *Bacterium thermophilum VII*, Chester, Man. Determ. Bact., 1901, 185.) From feces.

Bacterium subrubeum Kern. (Arb. bakt. Inst. Karlsruhe, *1*, Heft 4, 1896, 450; *Bacillus subrubeus* Nepveux, Thèse, Fac. Pharm., Nancy, 1920, 115.) From the intestines of birds.

Bacterium subsquamosum Migula. (*Bacterium squamosum longum* Kern, Arb. bakt. Inst. Karlsruhe, *1*, Heft 4, 1896, 458; Migula, Syst. d. Bakt., *2*, 1900, 335.) From the intestines of a dove.

Bacterium subthermophilum Migula. (*Bacillus thermophilus IV*, Rabinowitsch, Ztschr. f. Hyg., *20*, 1895, 157; Migula, Syst. d. Bakt., *2*, 1900, 344; *Bacterium thermophilum IV*, Chester, Man. Determ. Bact., 1901, 186.) From soil and feces.

Bacterium subtilis var. *galleriae* Chorine. (Ann. Inst. Past., *41*, 1927, 1120.) From diseased larvae of the bee moth (*Galleria mellonella*).

Bacterium tenax Kern. (Arb. bakt. Inst. Karlsruhe, *1*, Heft 4, 1896, 443.) From the stomachs of birds.

Bacterium terrae (Ucke) Chester. (*Streptobacillus terrae* Ucke, Cent. f. Bakt., I Abt., *23*, 1898, 1001; Chester, Man. Determ. Bact., 1901, 199.) From soil.

Bacterium truncatum Chester. (Bacillus No. 51, Conn, Storrs Agr. Exp. Sta., 1894, 81; Chester, Man. Determ. Bact., 1901, 195; not *Bacterium truncatum* Migula, Syst. d. Bakt., *2*, 1900, 407; not *Bacterium truncatum* Chester, *ibid.*, 157.) From milk.

Bacterium verrucosum Kern. (Arb. bakt. Inst. Karlsruhe, *1*, Heft 4, 1896, 434.) From the stomachs and intestines of birds.

Bacterium virgula (Duclaux) Migula. (*Tyrothrix virgula* Duclaux, Ann. Inst. Nat. Agron., *4*, 1882, 23; Migula, Syst. d. Bakt., *2*, 1900, 323.) From cheese.

Bacterium viride van Tieghem. (Van Tieghem, Bull. Soc. Bot. France, 1880, 174; *Bacillus viridis* Trevisan, I generi e le specie delle Batteriacee, 1889, 18.)

Cellulobacillus mucosus Simola. (Ann. Ac. Sc. Fenn., Ser. A, *34*, 1931; abst. in Cent. f. Bakt., II Abt., *86*, 1932, 89.) Thermophilic; cellulose decomposed quickly at 55° to 60°C, more slowly at 37°C.

Cellulobacillus myxogenes Simola (*loc. cit.*). Not slimy as above.

Clostridium gelatinosum Laxa. (Eine thermophilen Bacillus, Laxa, Cent. f. Bakt., II Abt., *4*, 1898, 362; Laxa, *ibid.*, *6*, 1900, 286; *8*, 1902, 154; *Bacterium saccharophilum* Migula, Syst. d. Bakt., *2*, 1900, 341; *Bacterium laxae* Chester, Man. Determ. Bact., 1901, 187.) From sugar factory wastes. Produces slime in sucrose solutions. Probably a variety of *Bacillus vulgatus* according to Sacchetti (Cent. f. Bakt., II Abt., *95*, 1936, 115).

Denitrobacterium thermophilum Ambroz. (Cent. f. Bakt., II Abt., *37*, 1913, 3.) From soil.

Lactobacillus sporogenes Horowitz-Wlassowa and Nowotelnow. (Cent. f. Bakt., II Abt., *87*, 1933, 331.) Resembles *Lactobacillus delbrueckii* but forms ellipsoidal, terminal spores.

Metabacterium polyspora Chatton and Perard. (Compt. rend. Soc. Biol., Paris, *65*, 1913, 1232.) The type species of the genus *Metabacterium*, characterized by forming one to eight spores in a single cell. From the caecum of guinea pigs. See Buchanan (Jour. Bact., *3*, 1918, 39).

Myxobacillus betae Gonnermann. (Oesterreich-Ungarische Ztschr. f. Zuckerind. u. Landwirtsch., *36*, 1907, 877; see Cent. f. Bakt., II Abt., *21*, 1908, 258.) Produces slime in sucrose solutions. Appears to be closely related to *Bacillus subtilis*.

Nitrosobacillus thermophilus Campbell. (Science, *75*, 1932, 23.) A thermophilic aerobic rod with swollen clavate sporangia; forms nitrites from ammonium salts. From surface layers of soil from North Carolina and Florida.

Semiclostridium commune, *S. citreum*, *S. flavum* and *S. rubrum* Maassen. (Arbt. a. d. biol. Abt. f. Land- u. Forstwirtsch. am kaiserl. Ges. Amt., *5*, 1907, 1.) Produce slime in sucrose solutions.

Genus II. **Clostridium** *Prazmowski.**

(Prazmowski, Untersuchungen über die Entwickelungsgeschichte und Fermentwirkung einiger Bacterien-Arten, Inaug. Diss., Leipzig, 1880, 23; *Vibrio* Müller, Vermium terrestrium et fluviatilum, *1*, 1773, 39; *Bacterium* Ehrenberg, Evertebrata, Berlin, 1828, (8?)**; *Metallacter* Perty, Zur Kenntniss kleinster Lebensformen, 1852, (180?); *Amylobacter* Trecul, Compt. rend. Acad. Sci., Paris, *61*, 1865, 435; *Bacillus* Cohn, Beitr. z. Biol. d. Pflanzen, *1*, Heft 2, 1872, 175; *Tyrothrix* Duclaux, Ann. Inst. Nat. Agron., *4*, 1882, (79?); *Pacinia* Trevisan, Atti della Accad. Fis.-Med.-Statist., Milano, Ser. 4, *3*, 1885, (83?); *Cornilia* Trevisan, I generi e le specie delle Batteriacee, Milano, 1889, 21; *Granulobacter* Beijerinck, Verhandl. d. k. Akad. v. Wetensch., Amsterdam, Tweedie Sect., Deel I, 1893, 4; *Bactridium*, *Paraplectrum*, *Diplectridium* and *Plectridium* Fischer, Jahrb. f. Wissensch. Botan., *27*, 1895, 139; *Granulobacillus* Schattenfroh and Grassberger, Cent. f. Bakt., II Abt., *5*, 1899, 702; *Streptobacillus* Rist and Khoury, Ann. Inst. Past., *16*, 1902, 70; *Botulobacillus*, *Butyribacillus*, *Cellulobacillus*, *Putribacillus* and *Pectobacillus* Orla-Jensen, Cent. f. Bakt., II Abt., *22*, 1909, 342–343; *Pectinobacter* Makrinov, Arch. Sci. Biol. (Russ.), *18*, 1915, 442; *Bacteroides* Castellani and Chalmers, Man. of Trop. Med., 3rd ed., 1919, 959; *Butyriclostridium* and *Putriclostridium* Orla-Jensen, Jour. Bact., *6*, 1921, 263; *Rivoltillus* and *Metchnikovillus* Heller, Jour. Bact., *6*, 1921, 550; *Omelianskillus*, *Macintoshillus*, *Douglasillus*, *Henrillus*, *Flemingillus*, *Vallorillus*, *Multifermentans*, *Hiblerillus*, *Welchillus*, *Stoddardillus*, *Arloingillus*, *Meyerillus*, *Novillus*, *Seguinillus*, *Reglillus*, *Robertsonillus*, *Nicollaierillus*, *Martellillus*, *Recordillus*, *Tissierillus*, *Putrificus*, *Ermengemillus* and *Weinbergillus* Heller, Jour. Bact., *7*, 1922, 5–9; *Peptoclostridium* Donker, Inaug. Diss., Delft, 1926, 23; *Botulinus*, *Chauvoea* and *Welchia* Pribram, Jour. Bact., *18*, 1929, 374; *Anaerobacillus*, *Verrucosus* and *Euclostridium* Janke, Cent. f. Bakt., II Abt., *80*, 1930, 490; *Butylobacter* Bakonyi, U. S. Letters Pat., 1,818,782, 1931; *Caduceus*, *Endosporus*, *Inflabilis*, *Palmula* and *Terminosporus* Prévot, Ann. Inst. Past., *61*, 1938, 76–86; *Acuformis* (syn. *Palmula*) Prévot, Man. d. Class., etc., 1940, 152.) From Greek, *clostridium*, a little spindle.

Rods, frequently enlarged at sporulation, producing clostridial or plectridial forms. The cells possess no catalase. Anaerobic or microaerophilic. Biochemically very active. Many species ferment carbohydrates producing various acids (frequently including butyric) and gas (CO_2, H_2 and sometimes CH_4). Others cause rapid putrefaction of proteins producing offensive odors. Commonly found in soil and in human or animal feces. Some species, while growing saprophytically on decomposing vegetable matter or on dead tissue within an animal host, form various toxic and lytic substances and are thereby pathogenic.

The type species is *Clostridium butyricum* Prazmowski.

Key to the species of genus **Clostridium.**

I. Strictly anaerobic.
  A. Not typically fermenters of cellulose.
    1. Do not characteristically produce distinctive pigments.
      a. Spores central, excentric, to subterminal.
        b. Spores oval.

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* Revised by Prof. R. S. Spray, School of Medicine, West Virginia University, Morgantown, West Virginia, November, 1938; further revision May, 1942.

** In a few instances the original records were inaccessible. In such cases the page is indicated as (8?). In all other cases the page indicates what is believed to be the earliest record of the designation cited.

c. Rods distinctly swollen at sporulation.
d. Motile.
e. Gelatin, or glucose gelatin, not liquefied.
f. Glucose fermented.
g. Coagulated albumin not liquefied.
h. Stormy fermentation, or at least active coagulation of milk. Also see hhh.
i. Glycerol not fermented.
j. Mannitol fermented.
k. Starch, lactose and sucrose fermented.
1. *Clostridium butyricum.*
kk. Starch not fermented. Lactose and sucrose fermented.
1a. *Clostridium beijerinckii.*
jj. Mannitol not fermented.
k. Starch and lactose not fermented.
1b. *Clostridium pasteurianum.*
ii. Glycerol fermented.
j. Mannitol not fermented.
k. Starch, lactose, sucrose and salicin fermented.
1c. *Clostridium multifermentans.*
hh. Milk slowly coagulated; not stormily. Also see hhh.
i. Glycerol and mannitol not fermented.
2. *Clostridium fallax.*
ii. Glycerol not recorded.
j. Acid, but no gas, from lactose and sucrose.
3. *Clostridium fissum.*
hhh. Milk not coagulated.
i. Glycerol not fermented.
4. *Clostridium difficile.*
gg. Coagulated albumin not recorded.
h. Milk acidified, but not coagulated.
5. *Clostridium viscifaciens.*
ee. Gelatin, or glucose gelatin, liquefied.
f. Glucose fermented.
g. Coagulated albumin not liquefied.
h. Milk slowly coagulated. Clot not digested.
i. Glycerol and mannitol not fermented.
j. Lactose fermented.
k. Sucrose not fermented. Salicin fermented.
6. *Clostridium septicum.*
kk. Sucrose fermented. Salicin not fermented.
7. *Clostridium feseri.*
ii. Glycerol fermented.
8. *Clostridium hemolyticum.*
hh. Milk acidified but not coagulated.
i. Glycerol fermented.
j. Mannitol not fermented.
k. Starch fermented. Lactose, sucrose and salicin

not fermented. Exotoxin formed; toxic on injection but not on feeding.

9. *Clostridium novyi.*

kk. Starch not recorded.

l. Lactose, sucrose and salicin not fermented.

m. Adonitol fermented.

10. *Clostridium botulinum.*

mm. Adonitol not fermented.

10a. *Clostridium botulinum.* Type C.

gg. Coagulated albumin slowly to rapidly liquefied.

h. Stormy fermentation, or at least active coagulation of milk. Clot not digested.

11. *Clostridium acetobutylicum.*

hh. Milk slowly and softly coagulated; not stormily. Clot slowly to rapidly digested.

i. Glycerol and mannitol not fermented. Also see iii.

j. Starch not recorded.

k. Lactose fermented.

12. *Clostridium aerofoetidum.*

kk. Lactose not fermented.

13. *Clostridium sporogenes.*

13a. *Clostridium sporogenes* var. *A. P. Marie.*

13b. *Clostridium sporogenes* var. *equine.*

13c. *Clostridium tyrosinogenes.*

13d. *Clostridium flabelliferum.*

13e. *Clostridium parasporogenes.*

ii. Glycerol fermented. Also see iii.

j. Mannitol not fermented.

14. *Clostridium parabotulinum* Types A and B.

iii. Glycerol not recorded.

j. Mannitol and starch not recorded.

k. Lactose and sucrose weakly fermented.

l. Gas formed from carbohydrates.

15. *Clostridium saccharolyticum.*

ll. Gas not formed from carbohydrates.

16. *Clostridium regulare.*

ff. Glucose not fermented. (Carbohydrates not fermented.)

g. Coagulated albumin not digested. Lab-coagulation of milk; increasing alkalinity. Clot digested.

17. *Clostridium hastiforme.*

gg. Coagulated albumin not recorded. Slow, mildly acid coagulation of milk. Clot digested.

18. *Clostridium subterminale.*

dd. Non-motile.

e. Gelatin, or glucose gelatin, not liquefied.

19. *Clostridium malenominatum.*

cc. Rods not swollen at sporulation.

d. Motile.
e. Gelatin, or glucose gelatin, liquefied.
f. Glucose fermented.
g. Coagulated albumin liquefied. Milk slowly coagulated. Clot slowly digested.
20. *Clostridium bifermentans.*
gg. Coagulated albumin not recorded.
h. Milk slowly coagulated; slimy.
i. Gas formed from glucose.
21. *Clostridium mucosum.*
ii. Acid but no gas from glucose.
22. *Clostridium pruchii.*
ee. Iron-gelatin (Spray), no growth.
23. *Clostridium cylindrosporum.*

dd. Non-motile.
e. Gelatin, or glucose gelatin, liquefied.
f. Glucose fermented.
g. Coagulated albumin not liquefied.
h. Milk stormily fermented. Clot not digested.
i. Glycerol fermentation variable.
j. Mannitol not fermented. Starch, lactose and sucrose fermented. Salicin rarely fermented. Types identified by specific toxin-antitoxin neutralization.
24. *Clostridium perfringens* Types A, B, C and D.

bb. Spores spherical.
c. Rods distinctly swollen at sporulation.
d. Motile.
e. Gelatin, or glucose gelatin, not liquefied.
f. Glucose fermented.
g. Coagulated albumin not liquefied.
h. Milk acidified; slowly and softly coagulated; not stormily. Clot not digested.
25. *Clostridium sphenoides.*
hh. Milk acidified but not coagulated.
26. *Clostridium innominatum.*

cc. Rods not swollen at sporulation.
d. Non-motile.
e. Gelatin, or glucose gelatin, not liquefied.
f. Glucose fermented.
g. Coagulated albumin not liquefied.
h. Milk acidified but not coagulated.
27. *Clostridium filiforme.*

aa. Spores terminal.
b. Spores distinctly oval to ellipsoid.
c. Rods distinctly swollen at sporulation.
d. Motile.
e. Gelatin, or glucose gelatin, not liquefied. Also see eee.
f. Glucose fermented.

g. Coagulated albumin not liquefied.
h. Milk slowly coagulated. Clot not digested.
i. Glycerol not fermented.
j. Mannitol fermented.
28. *Clostridium sartagoformum.*
jj. Mannitol not fermented.
29. *Clostridium paraputrificum.*
ff. Glucose not fermented.
g. Coagulated albumin not liquefied. Milk unchanged.
30. *Clostridium cochlearium.*
gg. Coagulated albumin not recorded.
h. Milk, or iron-milk (Spray), no growth.
i. Carbohydrates not fermented.
j. Ethyl alcohol fermented chiefly to caproic acid.
31. *Clostridium kluyverii.*
jj. Ethyl alcohol not fermented to caproic acid.
32. *Clostridium acidiurici.*
ee. Gelatin, or glucose gelatin, liquefied. Also see eee.
f. Glucose fermented.
g. Coagulated albumin liquefied.
h. Milk often, but not always, coagulated. Clot, if formed, not digested.
33. *Clostridium capitovale.*
hh. Milk acidified but not coagulated. Slow peptonization.
i. Glycerol and mannitol not recorded.
j. Starch not fermented.
34. *Clostridium parabifermentans.*
jj. Starch not recorded. Lactose weakly fermented.
35. *Clostridium ovalare.*
eee. Gelatin, or glucose gelatin, not recorded. Glucose fermented with acid but no gas.
36. *Clostridium zoogleicum.*
bb. Spores spherical, or nearly so.
c. Rods distinctly swollen at sporulation.
d. Motile.
e. Gelatin, or glucose gelatin, not liquefied. Also see eee.
f. Glucose fermented.
g. Coagulated albumin not liquefied.
h. Milk slowly coagulated, not stormily. Clot not digested. Also see hhh.
37. *Clostridium thermosaccharolyticum.*
hh. Milk not coagulated; unchanged. Also see hhh.
38. *Clostridium caloritolerans.*
hhh. Milk slowly alkalinized; casein slowly separated.
39. *Clostridium tetanoides.*
ee. Gelatin, or glucose gelatin, liquefied. Also see eee.
f. Glucose not fermented.

g. Coagulated albumin slowly liquefied.
h. Milk may show soft lab-coagulation. Clot not definitely digested.
40. *Clostridium tetani.*
hh. Milk shows slow, soft lab-coagulation. Clot slowly digested.
41. *Clostridium lentoputrescens.*
ff. Glucose weakly fermented.
g. Coagulated albumin slowly liquefied.
h. Milk variably coagulated. Clot, if formed, variably digested.
42. *Clostridium filamentosum.*
eee. Gelatin records at variance.
f. Glucose fermented.
g. Coagulated albumin not liquefied.
h. Milk not coagulated; unchanged.
43. *Clostridium tetanomorphum.*
dd. Non-motile.
e. Gelatin, or glucose gelatin, not liquefied.
f. Glucose fermented.
g. Coagulated albumin not recorded.
44. *Clostridium alcaligenes.*
ee. Gelatin, or glucose gelatin, liquefied.
f. Glucose fermented.
g. Coagulated albumin not liquefied.
45. *Clostridium angulosum.*
gg. Coagulated albumin liquefied.
46. *Clostridium putrefaciens.*
2. Characteristically produce pigments of varied colors.
a. Spores central, excentric, to subterminal.
b. Spores oval.
c. Rods distinctly swollen at sporulation.
d. Motile.
e. Gelatin, or glucose gelatin, not liquefied.
f. Black pigment formed around colonies in deep agar.
47. *Clostridium nigrificans.*
ff. Violet pigment formed in potato mash.
g. Indole is formed.
48. *Clostridium belfantii.*
gg. Indole is not formed.
48a. *Clostridium maggiorai.*
fff. Green pigment formed on potato slant.
g. Indole is formed.
48b. *Clostridium derossii.*
48c. *Clostridium ottolenghii.*
48d. *Clostridium paglianii.*
gg. Indole is not formed.
48e. *Clostridium lustigii.*
48f. *Clostridium sciavoi.*

ffff. Red pigment formed in potato mash.
g. Indole not recorded.
49. *Clostridium venturelli.*
ee. Gelatin, or glucose gelatin, liquefied.
f. Red to orange-red pigment formed, especially in starchy media.
g. Indole is not formed.
h. Stormy fermentation of milk. Clot slowly softened.
50. *Clostridium roseum.*
hh. Slow, spongy coagulation of milk. Clot slowly digested.
51. *Clostridium chromogenes.*
ff. Yellow-orange pigment formed in various media.
g. Indole is not formed.
h. Milk actively coagulated, not stormily. Clot is not digested.
52. *Clostridium felsineum.*
aa. Spores terminal.
b. Spores oval.
c. Rods distinctly swollen at sporulation.
d. Non-motile.
e. Gelatin, or glucose getamin, no liquefied.
f. Deep red pigment formed on potato slants.
53. *Clostridium carbonei.*
B. Typical fermenters of cellulose.
1. Do not characteristically produce distinctive pigments.
a. Spores terminal.
b. Spores distinctly oval to ellipsoid.
c. Rods distinctly swollen at sporulation.
d. Motile.
e. Gelatin, or glucose gelatin, liquefied. Ferments a variety of carbohydrates, other than cellulose, after prolonged cultivation.
54. *Clostridium spumarum.*
ee. Gelatin, or glucose gelatin, not recorded. Carbohydrates, other than cellulose, not fermented.
55. *Clostridium werneri.*
bb. Spores spherical, or nearly so.
c. Rods distinctly swollen at sporulation.
d. Non-motile.
56. *Clostridium cellulosolvens.*
2. Characteristic pigments produced in certain media.
a. Spores terminal.
b. Spores distinctly oval to ellipsoid. Rods distinctly swollen at sporulation.
57. *Clostridium dissolvens.*
bb. Spores spherical, or nearly so. Rods distinctly swollen at sporulation.
58. *Clostridium omelianskii.*

II. Microaerophilic. Grow customarily as anaerobes, but are able to produce scan sometimes atypical, growth on aerobic agar slants.

A. Not typically fermenters of cellulose.

1. Do not characteristically produce distinctive pigments.

a. Spores central, excentric, to subterminal. Spores oval. Rods distinctly swollen at sporulation.

59. *Clostridium carnis.*

ee. Gelatin, or glucose gelatin, liquefied.

f. Carbohydrates not fermented.

60. *Clostridium histolyticum.*

aa. Spores terminal. Spores distinctly oval to ellipsoid. Rods distinctly swollen at sporulation.

61. *Clostridium tertium.*

1. **Clostridium butyricum** Prazmowski. (Untersuch. ü. d. Entwickelungsgeschischte ü. Fermentwirk. einiger Bacterien-Arten, Inaug. Diss., Leipzig, 1880, 23; *Bacillus butyricus* Flügge, Die Mikroorg., 2 Aufl., 1886, 296.) From M. L., *acidum butyricum*, butyric acid.

Described from the original incomplete records of Prazmowski, as amplified by the studies of Adamson, Jour. Path. and Bact., *22*, 1919, 371, and of Hall, Jour. Inf. Dis., *30*, 1922, 467.

Rods: 0.7 by 5.0 to 7.0 microns, straight or slightly curved, with rounded ends, occurring singly, in pairs, in short chains and occasional long filaments. Motile. Spores oval, excentric to subterminal, swelling rods to clostridial forms. Gram-positive, becoming Gram-negative.

Granulose positive in clostridial stage (blue color with iodine).

Gelatin and glucose gelatin: Not liquefied.

Plain agar slant (anaerobic): Little or no growth.

Glucose agar surface colonies (anaerobic): Circular or slightly irregular, slightly raised, moist, creamy-white.

Deep glucose agar colonies: Biconvex, dense, yellowish-white, entire. Agar fragmented early by abundant gas.

Blood agar not hemolyzed.

Plain broth: Little or no growth.

Glucose broth: Abundant, diffuse turbidity; much gas.

Litmus milk: Acid and early coagulation. Litmus is reduced. Stormy fermentation; clot fragmented but not digested.

Indole not formed.

Nitrites not produced from nitrates.

Fixes atmospheric nitrogen.

Acid and gas from xylose, glucose, lactose, sucrose, starch, salicin, esculin and mannitol. Amygdalin, pectin, cellulose, glycerol and Ca-lactate not fermented.

Fermentation products include butyl, ethyl and iso-propyl alcohols, acetone, organic acids, H_2 and CO_2.

Coagulated albumin not liquefied.

Blood serum not liquefied.

Brain medium not blackened or digested.

Non-pathogenic for guinea pig and rabbit.

Grows well from 30°C to 37°C.

Anaerobic.

Source: Originally isolated from cheese. Commonly encountered in naturally soured milk, in naturally fermented starchy plant substances and in soil.

Habitat: Probably rather widely dispersed in soils rich in humus.

NOTE: Many butyric acid-producing anaerobes are recorded in the literature. The questionable purity and the incomplete descriptions, particularly of the older species, make it difficult to determine the degree of relationship of these species to *Clostridium butyricum* Prazmowski. The following list cites the outstanding historic or recently described species.

Ferment butyrique, Pasteur, Compt. rend. Acad. Sci., Paris, *52*, 1861, 345 (Vibrion butyrique, Pasteur, *ibid.*, 1261); *Bacillus amylobacter* van Tieghem, Bull. de la Soc. Botan. de France, *24*, 1877, 128 (*Metallacter amylobacter* Trevisan, Reale Ist. Lombardo d. Sci. e Lett., Rendiconti, 1879, 147; *Clostridium amylobacter* Holland, Jour. Bact., *5*, 1920, 217); *Bacterium navicula* Reinke and Berthold, Untersuch. a. d. Bot. Lab. d. Univ. Göttingen, *1*, 1879, 21 (*Amylobacter navicula* Wehmer, Cent. f. Bakt., II Abt., *4*, 1898, 696; *Bacillus navicula* Chester, Ann. Rept. Del. Col. Agr. Exp. Sta., *10*, 1898, 128; *Clostridium naviculum* Prévot, Ann. Inst. Past., *61*, 1938, 80); *Bacillus butylicus* Fitz, Ber. d. Deuts. Chem. Gesellsch., *15*, 1882, 867 (*Bacterium fitz* Buchner, Ztschr. f. Physiol. Chem., *9*, 1885, 384); Butylbacillus, Buchner, *ibid.*, 391; *Clostridium butyricum* (*Bacillus amylobacter*) *I*, *II*, *III*, Gruber, Cent. f. Bakt., *1*, 1887, 370–371; *Bacillus butylicus* Migula, Syst. d. Bakt., *2*, 1900, 598 (*Clostridium butyricum I*, Gruber, Cent. f. Bakt., *1*, 1887, 370); *Bacillus gruberi* Migula, *loc. cit.*, 599 (*Clostridium butyricum II*, Gruber, *loc. cit.*, 371); *Bacillus subanaerobius* Migula, *loc. cit.*, 600 (*Clostridium butyricum III*, Gruber, *loc. cit.*, 371); Bacille amylozyme, also bacille amylocyme, Perdrix, Ann. Inst. Past., *5*, 1891, 290 (*Bacillus amylozyma* Migula, Syst. d. Bakt., *2*, 1900, 626; *Bacillus amylozymicus* Peterson, Scott and Thompson, Biochem. Ztschr., *219*, 1930, 1; *Clostridium amylozyme* Prévot, Ann. Inst. Past., *61*, 1938, 79; *Clostridium* var. *amylozyme* Prévot, Man. d. Class., etc., 1940, 109); *Bacillus orthobutylicus* Grimbert, Ann. Inst. Past., *7*, 1893, 353; *Granulobacter butylicum* Beijerinck, Verhandl. d. K. Akad. v. Wetensch., Amsterdam, Tweedie Sectie, Deel I, 1893, 3 (*Clostridium butylicum* Donker, Thesis, Delft, 1926, 149; *Amylobacter butylicum* van Beynum and Pette, Cent. f. Bakt., II Abt., *93*, 1935, 200; this species is probably identical with *Clostridium butyricum I* Gruber, Cent. f. Bakt., I Abt., *1*, 1887, 370); *Granulobacter saccharobutyricum* Beijerinck, *loc. cit.*, 3, also in Arch. Néerland. d. Sci. Exactes et Nat., *29*, 1896, 1 (commonly identified with *Bacillus butylicus* Fitz, Ber. d. Deuts. Chem. Gesellsch., *15*, 1882, 867; *Bacillus humosus* Migula, Syst. d. Bakt., *2*, 1900, 600; *Clostridium saccharobutyricum* Donker, Thesis, Delft, 1926, 147; *Amylobacter saccharobutyricus* van Beynum and Pette, Cent. f. Bakt., II Abt., *93*, 1935, 200); *Bacillus saccharobutyricus* von Klecki, Cent. f. Bakt., II Abt., *2*, 1896, 169; *Bactridium butyricum* Chudiakow, Zur Lehre von der Anaerobiose (Russ.), Teil I, 1896, (?), cited by Rothert, Cent. f. Bakt., II Abt., *4*, 1898, 390; *Granulobacillus saccharobutyricus mobilis non-liquefaciens* Schattenfroh and Grassberger, Cent. f. Bakt., II Abt., *5*, 1899, 702 (bewegliche Buttersäurebacillus, Grassberger and Schattenfroh, Arch. f. Hyg., *42*, 1902, 219; *Bacillus saccharobutyricus mobilis* Hopffe, Ztschr. Infekrnkh. d. Haust., *14*, 1913, 396; *Bacillus amylobacter mobilis* Gratz and Vas, Cent. f. Bakt., II Abt., *41*, 1914, 509); *Plectridium pectinovorum* Störmer, Mitteil. d. Deuts. Landwirts. Gesellsch., *18*, 1903, 195 (Microbe du rouissage, Winogradsky, Compt. rend. Acad. Sci., Paris, *121*, 1895, 744; *Granulobacter pectinovorum* Beijerinck and van Delden, Arch. Néerland. d. Sci. Exactes et Nat., Ser. II, *9*, 1904, 423; *Clostridium pectinovorum* Donker, Thesis, Delft, 1926, 145); *Bacillus holobutyricus* Perdrix, Compt. rend. Soc. Biol., Paris, *57*, 1904, 481; *Bacillus amylobacter* Bredemann, Cent. f. Bakt., II Abt., *23*, 1909, 385 (*Clostridium amylobacter* Prévot, Ann. Inst. Past., *61*, 1938, 79); *Amylobacter nonliquefaciens* Ruschmann and Bavendamm, Cent. f. Bakt., II Abt., *64*, 1925, 359; *Clostridium intermedium* Donker, Thesis, Delft, 1926, 147 (Strain No. 3, Donker, *ibid.*, 39); *Clostridium butyricum iodophilum*

Svartz, Jour. Inf. Dis., *47*, 1930, 138 (*Clostridium iodophilum* Prévot, Ann. Inst. Past., *61*, 1938, 80); *Granulobacter saccharobutyricus immobile nonliquefaciens* McCoy, Fred, Peterson and Hastings, Jour. Inf. Dis., *46*, 1930, 121; *Bacillus amylobacter S* and *W*, Wertheim, U. S. Letters Pat., 1,917,676, 1933; *Clostridium tyrobutyricum* van Beynum and Pette, Cent. f. Bakt., II Abt., *93*, 1935, 208; *Clostridium polyfermenticum*, *Clostridium saccharopetum*, *Clostridium saccharophilicum* and *Clostridium saccharopostulatum* Partansky and Henry, Jour. Bact., *30*, 1935, 564.

1a. *Clostridium beijerinckii* Donker. (Donker, Thesis, Delft, 1926, 145.) Named for M. W. Beijerinck, the Dutch bacteriologist.

Has the general characters of *Clostridium butyricum*.

Distinctive character: Non-fermentation of starch.

Acid and gas from glucose, lactose, sucrose, inulin, galactose, fructose and mannitol. Glycerol and starch not fermented.

Source: From soil and fermenting plant tissues.

Habitat: Apparently widely distributed in agricultural soils.

1b. *Clostridium pasteurianum* Winogradsky. (Winogradsky, Arch. Sci. Biol. (Russ.), *3*, 1895, 330; *Clostridium pastorianum* Winogradsky, Cent. f. Bakt., II Abt., *9*, 1902, 43; *Bacillus pasteurianus* Lehmann and Neumann, Bakt. Diag., 4th Aufl., *2*, 1907, 82; *Bacillus pastorianus* Lehmann and Neumann, *ibid.*, 462; not *Bacillus pastorianus* Macé, Traité Prat. d. Bact., 4th ed., 1901, 957; *Bacillus winogradskyi* Weinberg et al., Les Microbes Anaér., 1937, 645.) Named for Louis Pasteur, the French scientist.

Probably related species: Bodily, Univ. Colorado Studies, *26*, 1938, 30, records 5 new species isolated from 10 strains received labeled *C. pasteurianum*. These have been designated as *Bacillus dulcitofermentans*, *Bacillus rhamnoticus*, *Bacillus inulofugus*, *Bacillus nonpentosus* and *Bacillus azoticus*.

Has the general characters of *Clostridium butyricum*.

Distinctive characters: Prolonged retention of the spore within a peculiar brush-like spore-capsule, and the non-fermentation of starch. Assimilates free atmospheric nitrogen.

Distinguished from *Clostridium beijerinckii* by the non-fermentation of lactose and mannitol, and from *Clostridium butyricum* by the non-fermentation of starch.

Acid and gas from glucose, sucrose, inulin, galactose, fructose and dextrin. Glycerol, starch, lactose and mannitol not fermented.

Source: Originally isolated from soil.

Habitat: Not determined, but apparently of restricted and local distribution in soil.

1c. *Clostridium multifermentans* Bergey et al. (*Bacillus multifermentans tenalbus* Stoddard, Lancet, *1*, 1912, 12; *Multifermentans tenalbus* Heller, Jour. Bact., *7*, 1922, 6; Bergey et al., Manual, 1st ed., 1923, 324.) From Latin, *multus*, many, and *fermentans*, fermenting.

Has the general characters of *Clostridium butyricum*, and is probably only a variety.

Distinctive character: Blood agar colonies show a zone of hemolysis in 24 hours.

Nitrites are produced from nitrates.

Distinguished from *Clostridium butyricum* by the above characters and by the fermentation of glycerol and non-fermentation of mannitol.

Distinguished from *Clostridium beijerinckii* by the fermentation of starch and of glycerol.

Distinguished from *Clostridium pasteurianum* by fermentation of starch and of lactose.

Acid and gas from glucose, fructose, galactose, maltose, lactose, sucrose, raffinose, starch, salicin, inulin and glycerol. Mannitol and dulcitol not fermented.

Source: Originally isolated from human gaseous gangrene.

Habitat: Found in soil and milk. Widely distributed in nature.

2. **Clostridium fallax** (Weinberg and Seguin) Bergey et al. (Bacille A, Weinberg and Seguin, Compt. rend. Soc. Biol., Paris, *78*, 1915, 277; *Bacillus fallax* Weinberg and Seguin, *ibid.*, 686; not *Bacillus fallax* Ornstein, Ztschr. f. Hyg., *91*, 1920, 159; *Vallorillus fallax* Heller, Jour. Bact., *7*, 1922, 6; Bergey et al., Manual, 1st ed., 1923, 325.) From Latin, *fallax*, deceptive.

Rods: 0.6 by 1.2 to 5.0 microns, occurring singly or rarely in pairs. Motile with peritrichous flagella. Encapsulated in body fluids. Spores rarely observed, oval, excentric to subterminal, swelling rods. Gram-positive.

Gelatin not liquefied.

Glucose agar surface colonies (anaerobic): Circular, flat, with transparent, crenated margin.

Glucose agar deep colonies: Lenticular, bean-shaped, irregular, smooth.

Agar slant (anaerobic): Grayish film.

Broth: Poor growth; slight diffuse turbidity.

Glucose broth: Abundant turbidity and gas. Clearing by sedimentation.

Indole not formed (Duffett, Jour. Bact., *29*, 1935, 576).

Litmus milk: Acid, slowly coagulated. Litmus reduced. Clot channeled by gas, but not digested.

Acid and gas from glucose, galactose, fructose, maltose, lactose, sucrose, inulin, salicin and starch. Glycerol and mannitol not fermented. Records vary in regard to action on lactose, inulin and salicin.

Coagulated albumin not liquefied.

Blood serum not liquefied.

Brain medium not blackened or digested.

Meat medium reddened; not blackened or digested.

Pathogenicity for guinea pig variable, and commonly lost in cultivation. Forms a weak exotoxin.

Optimum temperature not recorded; grows well at 37°C.

Anaerobic.

Source: From war wounds, appendicitis, and once from black-leg of sheep.

Habitat: Not determined, other than these sources.

3. **Clostridium fissum** (Debono) Bergey et al. (*Bacillus fissus* Debono, Cent. f. Bakt., I Abt., Orig., *62*, 1912, 232; Bergey et al., Manual, 1st ed., 1923, 332.) From Latin, *fissum*, separated.

Rods: Variable in size, rounded or square ends, occurring singly, in pairs and in chains and filaments. Motile. Spores small, oval, subterminal, slightly swelling rods. Gram-positive.

Gelatin: Not liquefied.

Deep gelatin colonies at 22°C: Small, brownish, globular, opaque and entire.

Deep glucose agar colonies: Small, white, globular. Gas is formed. No pigment formed.

Broth: Uniformly turbid.

Milk: Acid, coagulated after 3 days.

Indole not formed.

Acid and gas from glucose. Acid only in lactose and sucrose.

Coagulated albumin not liquefied.

Grows at 22°C and 37°C.

Anaerobic.

Distinctive character: All cultures smell strongly of butyric acid.

Source: From human feces.

Habitat: Not determined, other than this source.

4. **Clostridium difficile** (Hall and O'Toole) Prévot. (*Bacillus difficilis* Hall and O'Toole, Amer. Jour. Dis. Child., *49*, 1935, 390; *Clostridium difficilis* Prévot, Ann. Inst. Past. *61*, 1938, 84.) From Latin, *difficilis*, difficult.

Rods: Heavy-bodied. Actively motile.

Spores elongate, subterminal slightly swelling rods. Gram-positive.

Gelatin: Not liquefied.

Blood agar surface colonies (anaerobic): Irregular, flat and non-hemolytic.

Deep agar colonies: Minute, flat, opaque disks, becoming lobate.

Milk: Poor growth. Gas formed in traces, but milk unchanged.

Acid and gas from glucose, fructose, mannitol, salicin and xylose. Traces of gas, but no acid, from galactose, maltose, sucrose, lactose, raffinose, inulin and glycerol.

Coagulated albumin not liquefied.

Blood serum not liquefied.

Brain medium with iron is moderately blackened. Digestion not recorded.

Pathogenic for guinea pig and rabbit. Subcutaneous inoculation induces marked edema. Death may occur in from 1 to 9 days.

Toxicity: Glucose broth culture filtrates kill guinea pig and rabbit in 24 to 36 hours.

Grows well at 37°C.

Anaerobic.

Source: From feces of new-born infants.

Habitat: Not determined, other than this source.

5. **Clostridium viscifaciens** Sherman and Erb. (U. S. Pat., 2,017,572, 1935.) From Latin, *viscus*, birdlime, glue; *faciens*, making.

Rods: Vegetative cells 3 to 10 microns long; average about 6 microns. Motile. Spores oval, 1 by 2 microns, central to subterminal, sometimes swelling rods to club-like and spindle-shaped cells. Gram-negative.

Granulose reaction positive.

Gelatin: Not liquefied.

Plain agar slant (anaerobic): No growth.

Plain agar stab: No growth.

Liquid media: Tendency toward flocculent growth.

Milk: Acidified but not coagulated. Casein not digested.

Corn mash: Not fermented or digested.

Indole not formed.

Nitrites produced from nitrates.

Ammonia produced from peptone.

Acid, gas and alcohols produced from glucose and maltose.

Acid and gas from sucrose, lactose, dextrin, starch, glycerol, mannitol and salicin.

Calcium lactate: Not fermented.

Fermentation products include butyl alcohol (66 parts), iso-propyl alcohol (31 parts), and small amounts of acetone (3 parts).

Limiting reaction for growth: About pH 4.0 to about pH 8.0.

Optimum temperature 32°C to 36°C. Grows from 15°C to 42.5°C.

Anaerobic.

Distinctive character: In fermentable sugar broths it produces a copious flocculum.

Source: From soil and from grains and other plant materials in contact with soil.

Habitat: Apparently widely dispersed in agricultural soils.

6. **Clostridium septicum** (Macé) Ford.* (Vibrion septique, Pasteur and Joubert, Compt. rend. Acad. Sci., Paris, *85*, 1877, 113, and Bull. Acad. Med., 2° Ser., *6*, 1877, 794; *Vibrio pasteurii* Trevisan, Reale Ist. Lombardo d. Sci. e. Lett., Rendiconti, Ser. 2, *12*, 1879, 147; *Bacillus septicus* Macé, Traité Prat. d. Bact., 1st ed., 1888, 455; not *Bacillus septicus* Migula, Syst. d. Bakt., *2*, 1900, 646 (Unnamed aerobic bacillus, Babes, Sept. Proc. d. Kindesalters, Leipzig, 1889, 32; *Bacillus septicus ulceris gangraenosi*

* Note: In an editorial, Jour. Amer. Vet. Med. Assoc., *62*, 1922–23, 565, the name *Clostridium septicum* is ascribed to Winslow et al., Jour. Bact., 5, 1920, 191. Search fails to confirm the reference. Casual mention is not regarded as sufficient to establish priority. Hence, Ford is regarded as the author of this binomial.

Sternberg, Man. Bact., 1893, 472); not *Bacillus septicus* Klein, Micro-organisms and Disease, 1884, 78; *Cornilia pasteuri* Trevisan, I generi e le specie delle Batteriacee, 1889, 22; *Bacillus septicus gangrenae* Arloing, Leçons sur la tuberculose et certaines septicémies, Paris, 1892, 451; Vibriogene septique, Rosenthal, Compt. rend. Soc. Biol., Paris, *64*, 1908, 398; *Vibrio septique* LeBlaye and Guggenheim, Man. Prat. d. Diag. Bact., 1914, 438; *Rivoltillus vibrion* Heller, Jour. Bact., *7*, 1922, 6; *Bacillus parasarkophysematos* Miessner, Cent. f. Bakt., I Abt., Orig., *89* (Bhft.), 1922, 126, and Deuts. Tierarztl. Wchnschr., *30*, 1922, 416 (*Bacillus parasarcophysematos* Zeissler, Cent. f. Bakt., I Abt., Orig., *89* (Bhft.), 1922, 119); *Vibrio septicus* Rottgardt, Deuts. Tierarztl. Wchnschr., *34*, 1926, 553; Ford, Textbook of Bact., 1927, 726; *Clostridium septicus* Scott, Cornell Vet., *18*, 1928, 259; *Clostridium septique* Topley and Wilson, Princ. of Bact. and Immunol., 1st ed., *2*, 1929, 1161.) From Greek, *septicus*, putrefactive, septic.

Probable synonym: Bacillus of Ghon and Sachs, Cent. f. Bakt., I Abt., Orig., *34*, 1903, 289.

Identical or closely related species: *Clostridium balaenae* Prévot, Ann. Inst. Past., *61*, 1938, 81 (Walfischseptikämie Bacillus, Nielsen, Cent. f. Bakt., *7*, 1890, 269; Bacille de la septicémie de la baleine, Christiansen, Compt. rend. Soc. Biol., Paris, *83*, 1920, 324; Walfischbazillus, Christiansen, Cent. f. Bakt., I Abt., Orig., *84*, 1920, 127); *Bacillus gastromycosis ovis* Kitt, Bakt. u. Path. Mikros., 2 Aufl., 1893, 239 (Bradsotbacillus, Nielsen, Monats. Prakt. Tierhlk., *8*, 1897, 59); *Bacillus tumefaciens* Wilson, Lancet, *196*, 1919, 657 (*Clostridium tumefaciens* Prévot, Ann. Inst. Past., *61*, 1938, 81); not *Bacillus tumefaciens* Israilsky, Cent. f. Bakt., II Abt., *67*, 1926, 236; *Bacillus seu Clostridium sarcophysematos bovis* Kitt, Bakterienkunde u. Path. Mikros., 2 Aufl., 1893, 232 (*Bacillus sarcophysematos* Kitt, *ibid.*, Index, X; not *Bacillus sarcophysematos* Zeissler, Cent. f. Bakt., I Abt., Orig., *89* (Bhft.), 1922, 119.) (See *Clostridium feseri.*)

Confused in the older literature with Koch's bacillus of malignant edema, Mitt. a. d. kais. Gesundhts., *1*, 1881, 54 (*Bacillus oedematis maligni* Zopf, Die Spaltpilze, 3 Aufl., 1885, 88; *Clostridium oedematis malignis* Fischer, Jahrb. f. Wissen. Bot., *27*, 1895, (146?); *Bacillus oedematis* Schroeter, in Cohn's Kryptogamen-Flora v. Schlesien, *3*, *1*, 1886, 163; *Clostridium edematis* Holland, Jour. Bact., *5*, 1920, 218; *Clostridium oedematis-maligni* Bergey et al., Manual, 1st ed., 1923, 325).

It is commonly believed at present that Koch's bacillus of malignant edema was a culture of *Clostridium septicum* contaminated with *Clostridium sporogenes* or some closely related organism.

Described from Weinberg and Seguin, La Gang. Gaz., Paris, 1918, 79, and from Hall, Jour. Inf. Dis., *30*, 1922, 486.

Rods: 0.6 to 0.8 by 3.0 to 8.0 microns, rounded ends, occurring singly, in pairs and in short chains in cultures; long chains and filaments commonly predominate in body exudates. Motile, with peritrichous flagella. Spores oval, excentric to subterminal, swelling rods. Gram-positive.

Gelatin: Liquefied, with gas bubbles.

Agar surface colonies (anaerobic): Small, transparent, of variable shape.

Blood agar surface colonies (anaerobic): Delicate, flat, leaf-like, irregular. Hemolytic.

Deep agar colonies: Variable; usually finely filamentous, cottony, spherical.

Broth: Slight, diffuse turbidity, with clearing.

Litmus milk: Litmus reduced; slow coagulation and moderate gas. Clot not digested.

Indole not formed.

Nitrites produced from nitrates.

Acid and gas from glucose, fructose, galactose, maltose, lactose and salicin. Sucrose, inulin, mannitol and glycerol not fermented (Hall, *loc. cit.*, 489).

Coagulated albumin not liquefied.

Blood serum not liquefied.

Brain medium not blackened or digested.

Meat medium reddened; not blackened or digested.

Pathogenic for guinea pig, rabbit, mouse and pigeon. Forms an exotoxin for which an antitoxin is prepared.

Optimum temperature about 37°C.

Anaerobic.

Source: Originally isolated from animals inoculated with soil; later from malignant edema of animals, and from human war wounds and from appendicitis.

Habitat: Animal intestine, and in manured soils.

7. **Clostridium feseri** Trevisan. (Beweglichen Bakterien, Feser, Ztschr. f. Prakt. Vet.-Wissensch., *4*, 1876, 19; Trevisan, Atti Accad. Fis.-Med.-Stat. di Milano, *3*, 1885, 116; *Bacterium chauvoei* Arloing, Cornevin and Thomas, Le charbon symptomatique du boeuf, Paris, 2nd ed., 1887, 82; *Bacillus chauvoei* De Toni and Trevisan, in Saccardo, Sylloge Fungorum, *8*, 1889, 1004; *Bacillus chauvaei* Trevisan, I generi e le specie delle Batteriacee, 1889, 22; *Bacillus feseri* Kitt, Bacterienkunde, etc., 2 Aufl., 1893, 233; *Bacillus anthracis symptomatici* Kruse, in Flügge, Die Mikroorg., 3 Aufl., *2*, 1896, 245; *Bacillus carbonis* Migula, in Engler and Prantl, Die natür. Pflanzenfam., *1*, 1a, 1895, 26; *Butyribacillus chauvoei* Orla-Jensen, Cent. f. Bakt., II Abt., *22*, 1909, 342; *Bacillus gangraenae emphysematosae* Hutyra and Marek, Spez. Path. u. Ther. d. Haust., 3 Aufl., *1*, 1910, 39; *Bacillus chauvei* Holland, Jour. Bact., *5*, 1920, 217; *Clostridium chauvei* Holland, *ibid.*, 217; *Bacillus anthracis-symptomatici* Holland, *ibid.*, 217; *Clostridium anthracis-symptomatici* Holland, *ibid.*, 217; *Bacillus sarkophysematos* Miessner, Cent. f. Bakt., I Abt., Orig., *89* (Bhft.), 1922, 123 (*Bacillus sarcophysematos* Zeissler, *ibid.*, 119; not *Bacillus sarcophysematos* Kitt, Bakterienkunde, etc., 2 Aufl., 1893, Index, X); *Bacillus symptomaticus* Matouschek, Cent. f. Bakt., II Abt., *58*, 1923, 472; *Clostridium chauvoei* Scott, Jour. Inf. Dis., *38*, 1926, 262; *Clostridium chauvaei* Scott, Cornell Vet., *18*, 1928, 259.) Named for Feser, an early German bacteriologist.

Possible synonyms: Bacterio ocello cuneato, Rivolta, Giorn. di Anat., Fisiol. e Patol. d. Animali, Piso, *14*, 1882, 33; Bacillum cuneatum, Rivolta, *ibid.*, 67; Bacillum ocello-cuneatum, Rivolta, *ibid.*, 67; *Bacterium cuneatum* Rivolta, *ibid.*, 77; *Bacterium ocello cuneatum* Rivolta, *ibid.*, 78; *Bacillus sarcophysematosi* Peppler, Cent. f. Bakt., I Abt., *29*, 1901, 354.

Rods: 1.0 by 3.0 to 8.0 microns, occurring singly, in pairs and in short chains. Usually show a dark chromatic point near each end. Motile with peritrichous flagella. Spores oval, excentric to subterminal, swelling rods. Gram-positive.

Gelatin: Liquefied. Gas bubbles.

Agar surface colonies (anaerobic): Small, grayish, semi-opaque, filamentous.

Agar slant (anaerobic): Grayish, spreading growth.

Broth: Turbid, slightly peptolytic.

Litmus milk: Acid; slowly coagulated. Gas may be formed. Clot not digested.

Indole not formed (early studies record only a trace).

Acid and gas from glucose, fructose, galactose, maltose, lactose and sucrose. Inulin, salicin, mannitol, glycerol and dextrin not fermented (Hall, Jour. Inf. Dis., *30*, 1922, 486).

Coagulated albumin not liquefied.

Blood serum not liquefied.

Brain medium not blackened or digested.

Egg-meat medium: Small gas bubbles in 8 hours. Meat becomes pinkish and the liquid slightly turbid. No blackening or digestion.

Pathogenic for guinea pig, mouse and rabbit. Forms an exotoxin.

Optimum temperature 37°C. Can grow at 50°C.

Anaerobic.

Source: The cause of black leg, black quarter or symptomatic anthrax in cattle and other animals.

Habitat: Probably soil; especially where heavily manured.

8. **Clostridium hemolyticum** (Hall) Hauduroy et al. (*Clostridium hemolyticus bovis* Vawter and Records, Jour. Amer. Vet. Med. Assoc., *68* (N.S. *21*), 1925–26, 512; *Bacillus hemolyticus* Hall, Jour. Inf. Dis., *45*, 1929, 156; Hauduroy et al., Dict. d. Bact. Path., 1937, 125.) From Greek, *haemo*, blood; *lyticus*, dissolving.

Related species: *Clostridium hemolyticum* var. *sordelli* Hauduroy et al., *loc. cit.*, 126 (*Bacillus sp.* (?), Sordelli, Prado and Ferrari, Compt. rend. Soc. Biol., Paris, *106*, 1931, 142; Unnamed anaerobe of Matte, Inst. Biol. Soc. Nac. Agric., Chile, *2*A, 1921, (31?) (cited from Vawter and Records, *loc. cit.*, 172).

Rods: 1.0 to 1.3 by 3.0 to 5.6 microns, with rounded ends, occurring singly, in pairs and in short chains. Motile with long peritrichous flagella. Spores oval to elongate, subterminal, swelling rods. Gram-positive.

Gelatin: Liquefied.

Blood agar surface colonies (anaerobic): Light, diffuse growth. Blood hemolyzed.

Deep agar colonies: At first lenticular, becoming densely woolly masses with short peripheral filaments. Little or no gas formed.

Broth plus liver: Luxuriant diffuse turbidity, followed by agglutinative clearing. Moderate gas formed.

Milk: Acid and slow coagulation. Clot not digested.

Acid and gas from glucose, fructose, galactose and glycerol. Lactose, maltose, sucrose, raffinose, arabinose, xylose, inulin, salicin, mannitol and dulcitol not fermented. Subsequent studies show that pure galactose is not fermented (Records and Vawter, Nevada Agr. Exp. Sta., Bull. 173, 1945, 48 pp.).

Indole is formed.

Methyl red and Voges-Proskauer tests are negative.

Nitrites are not produced from nitrates.

Hydrogen sulfide is produced. The four characteristics given above are from Records and Vawter (*loc. cit.*, 30).

Coagulated albumin not liquefied.

Blood serum not liquefied.

Brain medium not blackened or digested.

Meat medium reddened, not blackened. No digestion.

Pathogenic and toxic for guinea pig and rabbit. Effect due to an unstable hemolytic toxin.

Grows well at 37°C.

Anaerobic.

Source: From blood and tissues of cattle dying of icterohemoglobinuria.

Habitat: Not determined. Thus far isolated only from animals.

9. **Clostridium novyi** (Migula) Bergey et al. (*Bacillus oedematis maligni No. II*, Novy, Ztschr. f. Hyg., *17*, 1894, 212; *Bacillus oedematis thermophilus* Kruse, in Flügge, Die Mikroorg., 3 Aufl., *2*, 1896, 242; *Bacillus novyi* Migula, Syst. d. Bakt., *2*, 1900, 872; *Bacterium oedematis thermophilus* Chester, Ann. Rept. Del. Col. Agr. Exp. Sta., *9*, 1897, 126; *Bacillus thermophilus* Chester, Man. Determ. Bact., 1901, 265; *Bacillus oedematiens* Weinberg and Seguin, Compt. rend. Soc. Biol., Paris, *78*, 1915, 507 (Bacille B, Weinberg and Seguin, *ibid.*, 177); *Novillus maligni* Heller, Jour. Bact., *7*, 1922, 7; *Clostridium oedematiens* Bergey et al., Manual, 1st ed., 1923, 326; Bergey et al., *idem; Clostridium thermophilum* Pribram, Jour. Bact., *22*, 1931, 430; *Clostridium novyi* Type A, Scott, Turner and Vawter, Proc., 12th Internat. Vet. Congr., *2*, 1934, 175.) Named for F. G. Novy, the American bacteriologist who first isolated this organism.

Related or possibly identical species: Neuen pathogenen anaeroben Bacillus, Kerry, Osterr. Ztschr. f. Wiss. Veterinärk., *5*, 1894, 228; *Bacterium nivosum* LeBlaye and Guggenheim, Man. Prat. d. Diag. Bact., 1914, 344 (Bacille neigeux, Jungano, Compt. rend. Soc. Biol., Paris, *62*, 1907, 677; Bacillo nevoso, Jungano, Il Tommasi, *2*, 1907, (731?); Gasödembazillus, Aschoff, Deuts. med. Wchnschr., *42*, 1916, 512; *Bacillus bellonensis* Sacquépée,

Compt. rend. Soc. Biol., Paris, *80*, 1917, 850 (Bacille de l'oedème gazeux malin, Sacquépée, *ibid.*, *78*, 1915, 316; *Clostridium bellonensis* Prévot, Ann. Inst. Past., *61*, 1938, 81); *Bacillus gigas* Zeissler and Rassfeld, Arch. Wiss. u. Prakt. Tierhlk., *59*, 1929, 419 (*Clostridium novyi* Type B, Scott et al., *loc. cit.*, 175; *Clostridium gigas* Prévot, Ann. Inst. Past., *61*, 1938, 82); not *Bacillus gigas* Trevisan, Atti. d. Accad. Fis.-Med.-Stat., Milano, Ser. 4, *3*, 1885, 96; *Clostridium novyi* Type C, Scott et al., *loc. cit.*, 175 (non-pathogenic bacillus of osteomyelitis of buffalo, Kraneveld, Nederl. Ind. Bl. Diergeneesk., *42*, 1930, 564; *Clostridium bubalorum* Prévot, Ann. Inst. Past., *61*, 1938, 82; *Bacillus osteomyelitis bubalorum* Prévot, Man. d. Class., etc., 1940, 123).

Rods: 0.8 to 0.9 by 2.5 to 5.0 microns, occurring singly and in pairs, not in chains. Motile with peritrichous flagella. Spores large, oval, subterminal, swelling rods. Gram-positive.

Gelatin: Liquefied and blackened.

Agar surface colonies (anaerobic): Small, white, with darker center, filamentous.

Agar slant (anaerobic): Grayish, spreading growth.

Deep agar colonies: Compact, opaque, becoming filamentous with age.

Broth: Turbid, with flocculent sediment.

Litmus milk: Acid, not coagulated. Litmus reduced.

Acid and gas from glucose, fructose, maltose, xylose, starch and glycerol. Lactose, sucrose, mannitol, dulcitol, inulin and salicin not fermented (Hall, Jour. Inf. Dis., *30*, 1922, 491).

Coagulated albumin not liquefied.

Blood serum not liquefied.

Brain medium not blackened or digested.

Pathogenic for guinea pig, rabbit, mouse, rat and pigeon. Forms an exotoxin, toxic on injection but not on feeding growth.

Optimum temperature 35°C to 38°C.

Anaerobic.

Source: From a guinea pig inoculated with peptonized casein; later from gaseous gangrene.

Habitat: Probably occurs in manured soils.

10. **Clostridium botulinum** (Van Ermengem) Holland. (*Bacillus botulinus* Van Ermengem, Cent. f. Bakt., I Abt., *19*, 1896, 443, and Ztschr. f. Hyg., *26*, 1897, 48; Holland, Jour. Bact., *5*, 1920, 217; *Ermengemillus botulinus* Heller, Jour. Bact., *7*, 1922, 8.) From Latin, *botulus*, sausage; M.L., *botulinus*, relating to sausage.

Clostridium botulinum comprises a number of toxic species, conveniently divided by Bengtson, U. S. Public Health Serv., Hyg. Lab. Bull. 136, 1924, 33, and by Meyer and Gunnison, Jour. Inf. Dis., *45*, 1929, 96 and 108, and by Gunnison and Meyer, Jour. Inf. Dis., *45*, 1929, 130, into a non-ovolytic (*Clostridium botulinum*) and an ovolytic (*Clostridium parabotulinum*) group. Authorities are not yet in agreement on fermentations and on variant sub-types, and the present groupings are only tentative, and subject to revision. Meyer and Gunnison cite some 15 sub-types on the basis of toxicity, agglutination and fermentation.

The original Van Ermengem strain is not available, and his description is inadequate for classification purposes. Description follows Bengtson (*loc. cit.*) who used Lister Institute Strain No. 94 (Brit. Med. Res. Counc., Spec. Rept. Ser. No. 12, 1917, 29; *ibid.*, Spec. Rept. Ser. No. 39, 1919, 26) as a type culture.

Rods: 0.5 to 0.8 by 3.0 to 8.0 microns, with rounded ends, occurring singly, in pairs and in short to occasional long chains. Motile with peritrichous flagella. Spores oval, central, subterminal, to terminal at maturation, slightly swelling rods. Gram-positive.

Gelatin: Liquefied.

Deep liver agar colonies: Fluffy with dense center.

Liver agar surface colonies (anaerobic): No perceptible growth.

Broth: Scant or no growth.

Liver broth: Luxuriant turbidity, with considerable gas.

Milk: Slowly increasing acidity. No coagulation. No gas.

Acid and gas from glucose, fructose, maltose, dextrin, glycerol, adonitol and inositol. Galactose, sucrose, lactose, raffinose, inulin, dulcitol, mannitol, xylose, arabinose, rhamnose and salicin not fermented (Bengtson, *loc. cit.*, 22–25).

Coagulated albumin not liquefied.

Blood serum not liquefied.

Brain medium not blackened or digested.

Meat medium not blackened or digested.

Pathogenic for animals. Forms a powerful exotoxin which is neurotoxic both on injection and feeding. Toxin is neutralized by *Clostridium parabotulinum* Type B antitoxin.

Optimum temperature 20° to 30°C (Van Ermengem, Ztschr. f. Hyg., *26*, 1897, 42); 30°C (Van Ermengem, Arch. d. Pharmacodyn., *3*, 1897, 213 and 499; see Williams and Reed, Jour. Inf. Dis., *71*, 1942, 227). Starin (Jour. Inf. Dis., *38*, 1926, 103), growth usually earlier at 37°C. Toxin production probably best around 28°C.

Anaerobic.

Source: Unknown. Culture received through Reddish from Robertson as *Bacillus botulinus* No. 94, Strain A, Institute of Infectious Diseases at Berlin. Similar strains have been isolated from canned foods.

Habitat: Probably occurs in soil.

10a. *Clostridium botulinum* Type C. (Toxin producing anaerobe, Bengtson, U. S. Pub. Health Repts., *37*, 1922, 164 and 2252; *Bacillus botulinus* Type C, Bengtson, *ibid.*, 38, and U. S. Pub. Health Serv., Hyg. Lab. Bull. 136, 1924, 7; *Clostridium luciliae* Bergey et al., Manual, 1st ed., 1923, 336.) From Latin, *botulus*, sausage.

Probably identical variety: *Clostridium parabotulinum equi* Theiler and Robinson, Rev. Gén. de Med. Vet., *36*, 1927, 199 (*Clostridium botulinum* Type E, Topley and Wilson, Principles of Bact. and Immunol., 2nd ed., 1936, 688; *Bacillus (Clostridium) botulinum D*, Weinberg and Ginsbourg, Données Recentes sur les Microbes Anaér., Paris, 1927, 107, but shown to be a Type C by Robinson, Union S. Africa, 16th Ann. Rept., Dir. Vet. Serv. and Animal Indus., 1930, 126; not *Clostridium botulinum* Type D, Meyer and Gunnison, *vide infra*). From a rat carcass presumably responsible for botulism in mules in South Africa.

Related varieties: *Bacillus parabotulinus* Seddon, Jour. Comp. Path. and Therap., *35*, 1922, 155 and 275 (*Clostridium parabotulinum* Ford, Text-Book of Bact., 1927, 743, although this name was used earlier in the "group" sense by Bengtson, U. S. Pub. Health Serv., Hyg. Lab. Bull. 136, 1924, 32). First isolated from bones considered the source of "bulbar paralysis" of cattle in Australia.

Clostridium parabotulinus bovis Theiler et al., Union S. Africa, Dept. Agric., 11th and 12th Repts. of the Dir. Vet. Educ. and Res., Part II, 1927, 1202 (*Clostridium botulinum* Type D, Meyer and Gunnison, Proc. Soc. Expt. Biol. and Med., *26*, 1928–29, 88, also Jour. Inf. Dis., *45*, 1929, 106; not *Clostridium botulinum* Type D, Weinberg and Ginsbourg, *vide supra*). From "lamziekte" of cattle in South Africa.

Clostridium botulinum Type E, Gunnison, Cummings and Meyer, Proc. Soc. Expt. Biol. and Med., *35*, 1936, 278. An organism received by them from the Russian Ukraine; source of isolation not stated.

Clostridium botulinum Type C may be regarded as a variety of *Clostridium botulinum*, as it has morphologic and cultural characters very similar to those of the Van Ermengem strain. Only divergent or additional characters are recorded here.

Rods: 0.5 to 0.8 by 3.0 to 6.0 microns, commonly slightly curved.

Agar stab: Slight growth. No gas.

Deep liver agar colonies: Lenticular, becoming loosely fluffy. Gas is formed.

Deep glucose agar colonies: Fluffy, without central nucleus. Gas is not formed.

Agar surface growth (anaerobic): Very scant, thin.

Broth: Scant growth.

Milk: Slowly increasing acidity. No coagulation. No digestion.

Acid and gas from glucose, fructose, galactose, maltose, glycerol and inositol. Dextrin is weakly fermented. Sucrose, lactose, raffinose, inulin, adonitol, dulcitol, mannitol, xylose, arabinose, rhamnose and salicin not fermented.

Pathogenic for animals. Forms a powerful exotoxin which is neurotoxic both on injection and feeding. Toxin is neutralized by homologous (Type Cα) antitoxin, but not by *Bacillus parabotulinus* Seddon (Type Cβ) antitoxin, although Seddon-toxin is neutralized by Type Cα antitoxin (Pfenninger, Jour. Inf. Dis., *35*, 1924, 347).

Grows well at 37°C.

Anaerobic.

Source: Larvae of blue-bottle fly (*Lucilia caesar*). Produces limberneck in chickens.

Habitat: Not determined, other than this source.

11. **Clostridium acetobutylicum** McCoy, Fred, Peterson and Hastings. (McCoy et al., Jour. Inf. Dis., *39*, 1926, 483; *ibid.*, *46*, 1930, 118; *Clostridium aceto-butylicum* Legg, U. S. Pat., 1,668,814, 1928; *Clostridium acetonobutylicum* Prévot, Ann. Inst. Past., *61*, 1938, 80; *Clostridium acetobutyricum* Prévot, Man. d. Class., etc., 1940, 110.) From Latin, *acetum*, vinegar and *butylicus*, butylic, relating to butyl alcohol.

Synonyms: *Bacillus granulobacter pectinovorum* Speakman, Jour. Biol. Chem., *41*, 1920, 319; *Clostridium acetonigenum* Donker, Inaug. Diss., Delft., 1926, 144.

Rods: Vegetative cells 0.6 to 0.72 by 2.6 to 4.7 microns; clostridia 1.3 to 1.6 by 4.7 to 5.5 microns. Straight, with rounded ends, occurring singly and in pairs, not in chains. No capsules. Motile with peritrichous flagella. Spores oval, excentric to subterminal, swelling rods to clostridia. Gram-positive, becoming Gram-negative.

Granulose reaction positive in clostridial stage.

Glucose gelatin: Liquefied.

Glucose agar surface colonies (anaerobic): Compact, raised, fairly regular.

Deep glucose agar colonies: Compact, typically lenticular and smooth. Agar fragmented early by abundant gas.

Blood agar not hemolyzed.

Pigmentation: None; colonies creamy-white, opaque.

Plain broth: No growth.

Glucose broth: Abundant, uniform turbidity, with much gas.

Litmus milk: Acid and active, often stormy, coagulation. Litmus reduced. Clot fragmented by gas, but not visibly digested. Proteolysis demonstrable, however, on milk agar.

Potato: Growth creamy-yellow. Potato digested to a yellow slime.

Corn mash: Much gas with butylic odor.

Indole not formed.

Acetylmethylcarbinol formed from many carbohydrates.

Nitrites not produced from nitrates.

Nitrites reduced to ammonia.

Acid and gas from arabinose, xylose, rhamnose, glucose, galactose, mannose, fructose, sucrose, maltose, lactose, raffinose, melezitose, starch, dextrin, inulin, glycogen, *d*-mannitol, α-methyl glucoside and salicin. Esculin, amygdalin and trehalose are weakly fermented. Melobiose, dulcitol, *d*-arabitol, perseitol, lactositol, sorbitol, erythritol, adonitol, inositol, quercitol, glycerol, pectin and cellulose are not fermented.

Fermentation products include acetone, butyl and ethyl alcohols, butyric and acetic acids, H_2 and CO_2.

Coagulated albumin cubes: Softened and browned by slow digestion.

Hydrogen sulfide produced from thiosulfate or sulfite; generally negative from proteinaceous sources.

Blood serum not liquefied.

Brain medium not blackened or digested.

Non-pathogenic for guinea pig and rabbit.

Optimum temperature probably about 37°C. Grows from 20°C to 47°C.

Anaerobic.

Source: From corn, molasses, potato and garden soil.

Habitat: Widely, but apparently sparsely, dispersed in agricultural soils.

NOTE: A number of acetone and butyl alcohol-fermenting anaerobes have been described. Present knowledge, however, does not permit any expression of the degree of possible relationship. Only a few well-described species are cited. *Bacillus butylicus B. F.*, Ricard, U. S. Pat., 1,385,888, 1921; *Bacillus butylaceticum* Freiberg, U. S. Pat., 1,537,597, 1925; *Clostridium butyricum* (*Prazmowski-Pike-Smyth*) Pike and Smyth, U. S. Pat., 1,655,435, 1928; *Butylobacter betae*, *Butylobacter sinense*, *Butylobacter solani* and *Butylobacter zeae* Bakonyi, British Pat., 328,723, 1930, and U. S. Pat., 1,818,-782, 1931; *Bacillus saccharobutyricus liquefaciens* McCoy et al., Jour. Inf. Dis., *46*, 1930, 121 (*Bacillus saccharobutyricum liquefaciens* Legg and Stiles, U. S. Pat., 1,927,813, 1933); *Clostridium saccharobutylicum-gamma* Izsak and Funk, U. S. Pat., 1,908,361, 1933 (*Clostridium saccharobutylicum gamma* and *Clostridium saccharobutyricum gamma* Izsak and Funk, U. S. Pat., 2,016,112, 1935); *Clostridium saccharo-acetobutylicum-alpha* McCoy, British Pat., 415,311, 1934; *Clostridium propyl-butylicum* Muller and Legg, British Pat., 415,312, 1934 (*Clostridium propyl butylicum* Legg and Stiles, U. S. Pat., 2,063,448, 1936); *Clostridium saccharobutyl-acetonicum* Loughlin, British Pat., 409,730, 1934, and U. S. Pat., 1,996,428, 1935, and 1,992,921, 1935; *Clostridium saccharo-acetobutylicum* Stiles and Legg, British Pat., 437,121, 1935 (*Clostridium saccharo-acetobutylicum* Legg, U. S. Pat., 2,063,449, 1936); *Clostridium saccharo-acetobutylicum-beta* Arzberger, U. S. Pat., 2,050,219, 1936; *Clostridium saccharo-acetobutylicum-gamma* Arzberger, *ibid.*; *Clostridium inverto-acetobutylicum* Legg and Stiles, British Pat., 437,120, 1935, and Legg, U. S. Pat., 2,063,449, 1936; *Clostridium* (*Bacillus*) *tetrylium* Owen, Mobley and Arroyo, Cent. f. Bakt., II Abt., *95*, 1936, 131; *Clostridium saccharobutyl-isopropyl-acetonicum* Loughlin, U. S. Pat., 2,085,666, 1937 (*Clostridium saccharo-butyl-isopropyl-acetonicum* Loughlin, *ibid.*, and U. S. Pat., 2,096,377, 1937).

12. **Clostridium aerofoetidum** (Weinberg and Seguin) Bergey et al. (Bacille D, Weinberg, Compt. rend. Soc. Biol., Paris, *79*, 1916, 117; *Bacillus aerofoetidus* Weinberg and Seguin, *ibid.*, 1028; *Bacillus aero-foetidus* McIntosh, Med. Res. Counc., Spec. Rept. Ser. No. 39, 1919, 42; *Seguinillus aerofoetidus* Heller, Jour. Bact., 7, 1922, 7; Bergey et al., Manual, 1st ed., 1923, 327.) From Latin, *aer*, air and *foetidus*, fetid.

Rods: 0.4 to 0.6 by 3.0 to 5.0 microns, occurring singly, in pairs and in short chains. Motile with peritrichous flagella. Spores rare, oval, subterminal, slightly swelling rods. Gram-positive.

Gelatin: Rapidly liquefied.

Agar surface colonies (anaerobic): Circular, transparent, with faintly bluish tint, fimbriate.

Deep agar colonies: Lenticular, becoming indented and lobate.

Blood agar not hemolyzed.

Glucose broth: Turbid; with sediment.

Litmus milk: Acid; slowly coagulated; followed by slow peptonization. Gas is formed.

Acid and gas from glucose, fructose, galactose, mannose, maltose, lactose, xylose, amygdalin, salicin, esculin and glycogen. Sucrose, inulin, glycerol and mannitol not fermented.

Coagulated albumin slowly liquefied.

Blood serum is liquefied.

Brain medium blackened and digested.

Meat medium reddened, then blackened and slowly digested.

Slightly pathogenic for guinea pig.

Optimum temperature 30°C to 35°C.

Anaerobic.

Source: From gaseous gangrene and from feces.

Habitat: Not determined other than these sources. Probably occurs in soil.

13. **Clostridium sporogenes** (Metchnikoff) Bergey et al. (*Bacillus sporogenes* var. *A*, Metchnikoff, Ann. Inst. Past., *22*, 1908, 944; Bergey et al., Manual, 1st ed., 1923, 329; not *Clostridium sporogenes* Holland, Jour. Bact., *5*, 1920, 220 (*Bacillus enteritidis sporogenes* Klein, Cent. f. Bakt., I Abt., *18*, 1895, 737; *Bacillus sporogenes* Migula, Syst. d. Bakt., *2*, 1900, 560; *Bacillus (enteritidis) sporogenes* and *Bacillus enteritidis* Klein, Local Govt. Bd., Ann. Rept. Med. Off., London, *33*, 1903–04, 442 and 443.) From Greek, *sporus*, seed; M.L., spore; *genes*, producing.

Two varieties, *A* and *B*, were described. *Bacillus sporogenes* var. *A*, Metchnikoff, *loc. cit.*, 944 (*Metchnikovillus sporogenes* Heller, Jour. Bact., *7*, 1922, 9; *Clostridium sporogenes* var. *A*, Prévot, Ann. Inst. Past., *61*, 1938, 83) is regarded as the typical form and is described here. Var. *B*, see *Clostridium bifermentans*.

Synonyms or probably related species: Oedembacillen, Koch, Mitt. a. d. kaiserl. Gesundheitsamte, *1*, 1881, 54; *Bacillus oedematis maligni* Zopf, Die Spaltpilze, 3 Aufl., 1885, 88 (not *Bacillus oedematis maligni* Liborius, Ztschr. f. Hyg., *1*, 1886, 158; *Bacillus oedematis* Migula, Syst. d. Bakt., *2*, 1900, 604); *Bacillus oedematis* Chester, Man. Determ. Bact., 1901, 292; *Clostridium oedematis maligni* Bergey et al., Manual 1st ed., 1923, 325 (see Species No. 6, *Clostridium septicum* Ford, p. 774): *Paraplectrum foetidum* Weigmann, Cent. f. Bakt., II Abt., *4*, 1898, 827 (Bacterie β, Weigmann, Cent. f. Bakt., II Abt., *2*, 1896, 155; *Bacillus weigmanni* Chester, Man. Determ. Bact., 1901, 300; *Plectridium foetidum* Weigmann, Mykologie der Milch, Leipzig, 1911, 70; *Bacillus anaerobius foetidus* LeBlaye and Guggenheim, Man. Prat. d. Diag. Bact., 1914, 329; *Endosporus foetidus* Prévot, Ann. Inst. Past., *61*, 1938, 75); *Bacillus saprogenes carnis* Salus, Arch. f. Hyg., *51*, 1904, 114 (*Bacillus saprogenes* Salus, *ibid.*, 115; not *Bacillus saprogenes I, II, III*, Herfeldt, Cent. f. Bakt., II Abt., *1*, 1895, 77; *Bacillus carnis saprogenes* Salus, Arch. f. Hyg., *51*, 1904, 124; *Plectridium saprogenes* Prévot, Ann. Inst. Past., *61*, 1938, 87); *Bacillus sporogenes coagulans* Debono, Cent. f. Bakt., I Abt., Orig., *62*, 1912, 229 (*Clostridium coagulans* Bergey et al., Manual, 1st ed., 1923, 335); Reading Bacillus, Donaldson and Joyce, Lancet, *2*, 1917, 448; *Bacillus putrificus verrucosus* Zeissler, Ztschr. f. Infkrnkh. u. Hyg. Haust., *21*, 1920–21, 13 (*Bacillus verrucosus* Lehmann and Süssmann, in Lehmann and Neumann, Bakt. Diag., 7 Aufl., *2*, 1927, 662).

Rods: 0.6 to 0.8 by 3.0 to 7.0 microns, with rounded ends, occurring singly, in pairs, or less frequently in short to long chains and filaments. Motile with peritrichous flagella. Spores oval, excentric to subterminal, swelling rods. Gram-positive.

Gelatin: Liquefied and blackened.

Agar surface colonies (anaerobic): Small, irregular, transparent, becoming opaque, yellowish-white, fimbriate.

Deep agar colonies: Woolly balls with dense, nodular center.

Agar slant (anaerobic): Grayish, opaque, spreading.

Blood agar is hemolyzed.

Broth: Turbid. Gas is formed. Putrid odor.

Litmus milk: Softly coagulated. Litmus reduced. Slow peptonization, leaving a dark, amber-colored liquid.

Indole formed (trace). Not formed (Hall, Jour. Inf. Dis., *30*, 1922, 482).

Nitrites not produced from nitrates.

Acid and gas from glucose, fructose,

galactose and maltose. Lactose, sucrose, salicin, glycerol, mannitol and inulin not fermented. (Records vary on many sugars.)

Coagulated albumin liquefied.

Blood serum liquefied to a dark, putrid liquid.

Brain medium blackened and digested. Foul odor.

Meat medium reddened, then blackened and digested with foul odor. Gas is produced. Tyrosin crystals not obvious.

Non-pathogenic to guinea pig and rabbit, other than a slight, temporary local tumefaction. Filtrate non-toxic on injection and feeding.

Optimum temperature 37°C. Can grow at 50°C.

Anaerobic.

Source: From intestinal contents, gaseous gangrene, and from soil.

Habitat: Common in soil, especially where heavily manured.

The following species are commonly regarded as variants of the typical *Clostridium sporogenes*.

13a. *Clostridium sporogenes* var. *A. P. Marie* Prévot, Ann. Inst. Past., *61*, 1938, 83 (Bacille anaérobie, Marie, Compt. rend. Soc. Biol., Paris, *93*, 1925, 21).

Resembles the typical *Clostridium sporogenes* except in the sharp but not putrid odor of its cultures.

Pathogenicity: Large abscesses are induced on subcutaneous injection into guinea pigs.

From spontaneous putrefaction of macerated pork.

13b. *Clostridium sporogenes* var. *equine* Prévot, Ann. Inst. Past., *61*, 1938, 83 (Unnamed anaerobe No. IV, Choukévitch, Ann. Inst. Past., *25*, 1911, 259).

Sporulation is delayed and restricted. Spores are long and almost rectilinear.

Litmus milk is coagulated, then the clot is digested after 3 to 4 weeks.

Coagulated albumin is slowly dissolved.

Not pathogenic for guinea pig or mouse.

From large intestine of horse.

13c. *Clostridium tyrosinogenes* (Hall) Bergey et al. (Culture No. 106, Hall and Finnerud, Proc. Soc. Expt. Biol. and Med., *19*, 1921–22, 48; *Bacillus tyrosinogenes* Hall, Abst. Bact., *6*, 1922, 7; not *Bacillus tyrosinogenes* Rusconi, as cited by Carbone, Ramazotti, Mazzucchi and Monti, Boll. Ist. Sieroter., Milan, *2*, 1921, (29?), see Clark and Smith, Jour. Bact., *37*, 1939, 278; Bergey et al., Manual, 1st ed., 1923, 329; *Clostridium sporogenes* var. *tyrosinogenes* Prévot, Ann. Inst. Past., *61*, 1938, 83.) From Greek, *tyrus*, cheese; M. L., *tyrosinum*, tyrosine; *genes*, producing.

Ferments monosaccharides but not higher carbohydrates (Hall, Jour. Inf. Dis., *30*, 1922, 482).

Traces of gas, but no acid, from glycerol, sorbitol, mannose, xylose, lactose, sucrose, arabinose, galactose, salicin, inulin, dextrin and starch (F. E. Clark, personal communication).

Distinctive character: Forms large amounts of tyrosin which precipitate in cultures in protein media.

Source: Originally isolated from a culture erroneously labeled *Bacillus tetani*. Later isolated from an amputated arm.

Habitat: Not determined. Only two isolations on record.

13d. *Clostridium flabelliferum* Sturges and Reddish. (Fish-tailed putrefactive anaerobe, Reddish and Sturges, Abst. Bact., *8*, 1924, 5; Sturges and Reddish, Jour. Bact., *11*, 1926, 37; *Clostridium sporogenes* var. *caudapiscis* Prévot, Ann. Inst. Past., *61*, 1938, 83.) From Latin, *flabellum*, a little fan; *fer*, bearing.

Glucose agar surface colonies (anaerobic): Coarse, raised, with long peripheral intertwining outgrowths.

Deep plain agar colonies: Irregular, becoming woolly.

Sucrose is fermented (in contrast with *Clostridium sporogenes*).

Distinctive character: Spores are long

retained within the sporangium, of which the distal end frays out to fibrils, giving the characteristic fish-tail appearance. Otherwise closely resembles *Clostridium sporogenes*.

Source: From soured hams and from salt.

Habitat: Not determined, other than these sources.

13e. *Clostridium parasporogenes* (Bulloch et al.) Bergey et al. (Bacillus Type XII, McIntosh and Fildes, Med. Res. Counc., Spec. Rept. Ser. No. 12, 1917, 36; *Bacillus parasporogenes* Bulloch et al., Med. Res. Counc., Spec. Rept. Ser. No. 39, 1919, 39; Bergey et al., Manual, 1st ed., 1923, 327; *Clostridium sporogenes* var. *parasporogenes* Prévot, Ann. Inst. Past., *61*, 1938, 83.)

Deep agar colonies: Lenticular to slightly irregular. Not woolly.

Pathogenic for young guinea pigs. Filtrate non-toxic on injection or on feeding.

Optimum temperature 30°C to 35°C.

Distinctive character: Resembles *Clostridium sporogenes*, but does not form woolly colonies in deep agar, and is agglutinatively distinct. Probably merely a variety.

Source: From gaseous gangrene.

Habitat: Not determined. Probably occurs in soil.

14. **Clostridium parabotulinum** Bengtson. (U. S. Pub. Health Serv., Hyg. Lab. Bull. 136, 1924, 32; Types A and B, Burke, Jour. Bact., *4*, 1919, 556; *Clostridium botulinum* Types A and B, Bergey et al., Manual, 1st ed., 1923, 328.) From Latin, *para*, like; M.L., *botulinum*, a species name.

Note: This group comprises the putrefactive (ovolytic) species, including strains commonly referred to as *Memphis* and *Canton* (Type A), and *Nevin* (Type B). Growth of these types is more easily obtained than with the *Clostridium botulinum* strains, and the reactions are more obvious.

Gunnison and Meyer (Jour. Inf. Dis., *45*, 1929, 130) propose an intermediate group between *Clostridium botulinum* and *Clostridium parabotulinum*, which they call *Clostridium metabotulinum*. Such a group would provisionally include certain European Type B strains, the Australian Type C, certain American Type C strains, and the South African Type D.

Rods: 0.5 to 0.8 by 3.0 by 8.0 microns, with rounded ends, occurring singly, in pairs, and in short chains. Motile with peritrichous flagella. Spores oval, subterminal, distinctly swelling rods. Gram-positive.

Gelatin: Liquefied.

Deep liver agar colonies: Type A tend to be restricted to compact disks, with sharp outline and small, opaque nucleus at periphery. Type B tend rather to form loose, woolly colonies (indicative only).

Liver agar surface growth (anaerobic): Profuse, moist.

Broth: Fairly abundant diffuse turbidity. Many strains spontaneously agglutinate.

Liver broth: Luxuriant turbidity. Profuse gas.

Milk: Slight acidity; slow curdling precipitation, with subsequent digestion and darkening.

Fermentation records are variable: Acid and gas from glucose, fructose, maltose, dextrin, glycerol and salicin. Galactose, sucrose, lactose, rhamnose, raffinose, inulin, adonitol, dulcitol, mannitol, xylose, arabinose and inositol not fermented (Bengtson, *loc. cit.*, 22–25).

Coagulated albumin liquefied: Action of Type B usually more marked than that of Type A.

Blood serum liquefied.

Brain medium blackened and digested, with putrefactive odor.

Meat medium blackened and digested. Putrefactive odor. Tyrosine crystals not observed.

Pathogenic for animals. Forms a powerful exotoxin which is neurotoxic both on injection and feeding, and which

is neutralized only by the homologous type antitoxin.

Optimum temperature: Records at variance. Grows best at 35 to 37°C. Toxin production best at about 28°C.

Anaerobic.

Distinctive character: Types are identified chiefly by protection tests with known-type antitoxin, and to less extent by agglutination.

Source: Chiefly from spoiled, non-acid canned goods, from soil and from silage.

Habitat: Found rather widely dispersed in soil.

15. **Clostridium saccharolyticum** Bergey et al. (*Bacillus sporogenes saccharolyticus* Distaso, Cent. f. Bakt., I Abt., Orig., *59*, 1911, 100; Bergey et al., Manual, 1st ed., 1923, 334.) From Greek, *saccharum*, sugar; *lyticus*, dissolving, digesting.

Rods: Short, rounded ends, occurring singly, in pairs and in short chains. Motile. Spores large, oval, excentric to subterminal, swelling rods. Gram-positive.

Gelatin: Liquefied.

Deep glucose agar colonies: Gray, biconvex, lenticular, granular, entire. Gas is formed.

Broth: Turbid.

Milk: Soft coagulation; casein precipitated, then peptonized, leaving a clear, yellow-amber supernatant fluid.

Indole is formed.

Acid and gas feebly formed from glucose. Lactose and sucrose feebly, or doubtfully, fermented.

Coagulated albumin slowly liquefied.

Grows well at 37°C.

Anaerobic.

Distinctive character: All cultures give a mixed butyric and fecal odor.

Source: From feces of a chimpanzee.

Habitat: Not determined, other than this source.

16. **Clostridium regulare** Bergey et al. (*Bacillus sporogenes regularis* Distaso, Cent. f. Bakt., I Abt., Orig., *59*, 1911, 100; Bergey et al., Manual, 1st ed., 1923, 334.) From Latin, straight.

Long rods: With rounded ends, occurring singly and in pairs. Motile. Spores oval, small, subterminal, slightly swelling rods. Gram-positive.

Gelatin: Liquefied.

Deep agar colonies: Small, opaque, irregular.

Milk: Acid; slowly coagulated, then clot slowly digested.

Indole formed in small quantity.

Slight acidity from glucose, lactose and sucrose. Gas is not formed. Odor of scatol and valerianic acid.

Coagulated albumin slowly liquefied.

Grows at 37°C.

Anaerobic.

Source: From human feces.

Habitat: Not determined, other than this source.

17. **Clostridium hastiforme** MacLennan. (A4, Cunningham, Cent. f. Bakt., II Abt., *82*, 1930–31, 487, and B4a, Cunningham, *ibid.*, *83*, 1931, 11; MacLennan, Jour. Path. and Bact., *49*, 1939, 543.) From Latin, resembling a spear.

Rods: Slender, 0.3 to 0.6 by 2.0 to 6.0 microns, with rounded ends, occurring singly, in pairs, and rarely in short chains. Filaments not observed. Motile, with delicate peritrichous flagella; motility persists even after sporulation. Spores ellipsoidal, subterminal, swelling rods. Polar-cap of protoplasm remains long attached to free spores. Gram-positive.

Gelatin: Rapidly liquefied. Blackening not recorded.

Plain agar surface colonies (anaerobic): Minute translucent dots, becoming irregularly round, granular, grayish-white, with opaque center and delicate translucent border.

Blood agar surface colonies (anaerobic): As above, but larger and more opaque. Old colonies show grayish pigmentation. No hemolysis.

Deep plain agar colonies: Small, irregularly round with coarsely filamentous

border. A little gas is occasionally formed.

Broth: Transient uniform turbidity, quickly settling as a heavy, white, flocculent deposit. Culture assumes a cheesy odor.

Milk: Abundant growth, with lab-coagulation in 2 to 3 days. No increase in acidity; becoming slightly alkaline. Clot completely digested in 10 to 14 days, leaving a white, semi-translucent fluid of cheesy odor.

Indole not formed.

Ammonia not formed.

Hydrogen sulfide not formed.

Glucose not fermented.

Carbohydrates not fermented.

Egg medium: No digestion or other visible change.

Coagulated albumin not digested or blackened.

Blood serum not digested or blackened.

Meat medium not digested or blackened, even in presence of metallic iron. Meat particles slightly reddened.

Brain medium not digested or blackened.

Grows well between 22°C and 37°C.

Anaerobic.

Non-pathogenic to guinea pigs on subcutaneous inoculation (Cunningham, Cent. f. Bakt., II Abt., *83*, 1931, 12).

Source: Originally isolated by Cunningham as a dissociant from a culture of *Bacillus saccharobutyricus* von Klecki. Later isolated by MacLennan; 1 strain from a culture of *Clostridium sporogenes*, and 2 strains from street dust.

Habitat: Not determined, other than these sources.

18. **Clostridium subterminale** (Hall and Whitehead) *comb. nov.* (*Bacillus subterminalis* Hall and Whitehead, Jour. Inf. Dis., *41*, 1927, 66.) Named from the characteristic position of the spores.

Rods: Occurring singly, in pairs and rarely in short chains. Motile. Spores oval, subterminal, swelling rods. Gram-positive.

Gelatin: Slowly liquefied, with slight turbidity and black sediment.

Blood agar surface colonies (anaerobic): Delicate. At first mildly, later actively, hemolytic.

Deep agar colonies: Opaque, compact, biconvex or lobate discs.

Agar slant (anaerobic): No surface growth.

Glucose broth: Turbidity, but no acid or gas formed.

Indole not formed.

Milk: Slowly coagulated (2 to 3 days), with mild acidity and gas. Slow but complete digestion of casein (8 to 18 days).

Glucose, fructose, galactose, maltose and lactose not fermented.

Brain medium: Slight turbidity in supernatant fluid. Slight gas formation and slow digestion.

Iron brain medium: Blackened in 2 to 3 days.

Tyrosin crystals not observable.

Non-pathogenic to guinea pigs on subcutaneous injection.

Grows well at 37°C.

Obligately anaerobic.

Source: From an African arrowhead.

Habitat: Not determined, other than this source.

19. **Clostridium malenominatum** (Weinberg et al.) *comb. nov.* (Pseudo-coli anaérobie, Jungano, Compt. rend. Soc. Biol., Paris, *65*, 1908–09, 457; *Bacillus pseudo-coli anaérobie* Jungano and Distaso, Les Anaérobies, 1910, 162; *Bacillus pseudocoli anaerobius* LeBlaye and Guggenheim, Man. Prat. d. Diag. Bact., 1914, 345; *Bacillus malenominatus* Weinberg et al., Les Microbes Anaérobies, 1937, 763; *Paraplectrum malenominatum* Prévot, Ann. Inst. Past., *61*, 1938, 75.) From Latin, meaning badly named.

Rods: Short, cocco-bacillary, becoming elongated to short filaments in old cultures—especially in sugar broth. Ends rounded. Distinct bipolar staining tendency. Non-motile. Capsulated, especially in body fluids. Spores oval,

subterminal, slightly swelling rods. Gram-negative.

Gelatin: No growth.

Deep agar colonies: Small, round, very regular, almost transparent. Gas not formed.

Plain broth: Uniform turbidity, settling after 48 hours, forming a fine, powdery sediment.

Indole not produced.

Milk: Growth with no coagulation.

Glucose and sucrose not fermented.

Coagulated albumin: Not attacked.

Meat medium: Abundant growth. No record of changes. Capsules are demonstrable in this medium.

Very pathogenic for guinea pigs, which die of septicemia in 24 hours after intraperitoneal inoculation. Less pathogenic for rabbit, which dies after one week.

Toxin not demonstrable in cultures.

Grows at 22°C to 37°C.

Obligately anaerobic.

Source: From feces of a diarrheal infant.

Habitat: Not determined, other than this single isolation.

20. **Clostridium bifermentans** (Weinberg and Seguin) Bergey et al. (*Bacillus bifermentans sporogenes* Tissier and Martelly, Ann. Inst. Past., *16*, 1902, 894; *Bacillus bifermantans* Weinberg and Seguin, La Gangrène Gazeuse, Paris, 1918, 128; *Martellillus bifermentans* Heller, Jour. Bact., *7*, 1922, 8; Bergey et al., Manual, 1st ed., 1923, 323.) From Latin, *bis*, twice, and *fermentum*, a ferment.

Closely related if not identical species: *Bacillus centrosporogenes* Hall, Jour. Inf. Dis., *30*, 1922, 464 (*Clostridium centrosporogenes* Bergey et al., Manual, 1st ed., 1923, 322); *Bacillus oedematis sporogenes* Sordelli, Compt. rend. Soc. Biol., Paris, *89*, 1923, 55 (Anaérobie agent de gangrène gazeuse, Sordelli, *ibid.*, *87*, 1922, 838; *Bacillus sordelli* Hall and Scott, Jour. Inf. Dis., *41*, 1927, 329; *Bacillus sporogenes oedematis* Piening, Thesis, Hanover, 1931, (?), cited from McCoy and McClung, The Anaer. Bact., etc., *2*, 1939, 492; *Clostridium sordelli* Prévot, Ann. Inst. Past., *61*, 1938, 83); *Clostridium oedematoides* Meleney, Humphreys and Carp, Proc. Soc. Expt. Biol. and Med., *24*, 1926–27, 677.

Varying degrees of virulence and toxicity occur in the above group. The more toxic and virulent strains are commonly referred to as *Bacillus sordelli*, although otherwise an apparently homogeneously organized group.

Probable synonyms: *Clostridium foetidum* Liborius, Ztschr. f. Hyg., *1*, 1886, 160 (*Cornilia foetida* Trevisan, I generi e le specie delle Batteriacee, 1889, 22; *Bacillus foetidus* Chester, Ann. Rept. Del. Col. Agr. Exp. Sta., *10*, 1898, 128; not *Bacillus foetidus* Trevisan, *loc. cit.*, 16); *Bacillus liquefaciens magnus* Lüderitz, Ztschr. f. Hyg., *5*, 1889, 146 (*Cornilia magna* Trevisan, *loc. cit.*, 22; *Bacillus magnus* Herfeldt, Cent. f. Bakt., II Abt., *1*, 1895, 78; *Bacillus magnus liquefaciens* LeBlaye and Guggenheim, Man. Prat. d. Diag. Bact., Paris, 1914, 327; *Bacillus foetidus clostridiiformis* LeBlaye and Guggenheim, *idem*, 327); *Clostridium foetidum carnis* Salus, Arch. f. Hyg., *51*, 1904, 121 (*Clostridium carnis foetidum* and *Clostridium foetidum* Salus, *ibid.*, 121 and 124; *Clostridium carnofoetidus* McCrudden, Jour. Biol. Chem., *8*, 1910–11, 109; *Clostridium carnofoetidum* Prévot, Ann. Inst. Past., *61*, 1938, 84); *Bacillus sporogenes* var. *B*, Metchnikoff, Ann. Inst. Past., *22*, 1908, 944 (*Clostridium sporogenes* var. *B*, Prévot, Ann. Inst. Past., *61*, 1938, 83); *Bacillus sporogenes foetidus* Choukévitch, Ann. Inst. Past., *25*, 1911, 257 (*Bacillus foetidus* Choukévitch, *ibid.*, 258); *Bacillus putrificus tenuis* Zeissler, Ztschr. f. Infkrnkh. u. Hyg. Haust., *21*, 1920–21, 13; *Bacillus nonfermentans* Hall and Whitehead, Jour. Inf. Dis., *41*, 1927, 65.

Rods: 0.8 to 1.0 by 5.0 to 6.0 microns, occurring singly, in pairs, and in short chains. Spores oval, central to excentric, not distinctly swelling rods. Motile in very young cultures only (less than 24 hours old). Gram-positive.

Gelatin: Liquefied and blackened.

Agar surface colonies (anaerobic): Circular, crenated to amoeboid.

Blood agar surface colonies (anaerobic): Small, transparent, hemolytic, becoming opaque, yellowish, spreading.

Broth: Turbidity and gas. Thick mucoid sediment.

Litmus milk: Slowly coagulated. Slowly peptonized, with little gas.

Indole is formed.

Nitrites not produced from nitrates.

Hydrogen sulfide is produced.

Acid and gas from glucose, fructose, mannose and maltose. Lactose, sucrose and inulin not fermented. Records suggest variability in glycerol and salicin.

Coagulated albumin rapidly liquefied and blackened.

Blood serum liquefied and blackened.

Brain medium digested and blackened.

Egg-meat medium digested and blackened. Tyrosin crystals in 8 to 10 days.

Pathogenicity: Variable with the strain; some kill rabbits in 24 hours; others produce only slight edema, while some show no effect.

Toxicity: Likewise variable, from acute to none.

Optimum temperature from 30°C to 37°C. Can grow at 50°C.

Anaerobic.

Source: Originally from putrid meat; subsequently from gaseous gangrene.

Habitat: Occurs commonly in feces, soil and sewage. Widely distributed in nature.

21. **Clostridium mucosum** (Klein) Bergey et al. (*Bacillus mucosus* Klein, Cent. f. Bakt., I Abt., *29*, 1901, 991; not *Bacillus mucosus* Zimmermann, Die Bakt. unserer Trink- u. Nutzwässer, Chemnitz, *2*, 1894, 8; *Bacterium mucosum* Migula, Syst. d. Bakt., *2*, 1900, 315; *Bacillus kleinii* Buchanan and Hammer, Iowa Agric. Exp. Sta. Res. Bull. 22, 1915, 276; not *Bacillus kleinii* Migula, Syst. d. Bakt., *2*, 1900, 766; not *Bacillus kleinii* Trevisan, *in litt.* cited from De Toni and Trevisan, in Saccardo, Sylloge Fungorum, *8*, 1889, 946; *Clostridium kleinii* Bergey et al., Manual, 1st ed., 1923, 321; Bergey et al., Manual, 4th ed., 1934, 472; not *Clostridium mucosum* Simola, cited from Prévot, Man. d. Class., etc., 1940, 112; *Endosporus mucosus* Prévot, Ann. Inst. Past., *61*, 1938, 75.) From Latin, slimy.

Rods: 1.3 by 2.0 to 5.0 microns, occurring singly, in pairs and in chains. Motile. Spores oval, central, not swelling rods. Gram-negative (Klein, *loc. cit.*). Young cultures Gram-positive (Buchanan and Hammer, *loc. cit.*).

No growth in media without carbohydrates.

Glucose gelatin: Slowly liquefied.

Glucose gelatin surface colonies (anaerobic): Small, gray.

Glucose gelatin stab: Villous growth. Slow liquefaction.

Glucose agar slant (anaerobic): Thin, veil-like layer. Slimy condensation water.

Glucose broth: Turbid. Gas bubbles.

Litmus milk: Acid; slowly coagulated, slimy. Gas formed. Odor of butyric acid.

Potato: No growth.

Indole not formed.

Nitrites not produced from nitrates.

Acid and gas from glucose.

Blood serum: No growth.

Non-pathogenic.

Grows at 37°C.

Anaerobic.

Source: Blood sausage (Blutwurst).

Habitat: Not determined, other than this source.

22. **Clostridium pruchii** (Buchanan and Hammer) Bergey et al. (*Bacillus lactis pruchii* Conn, Esten and Stocking, 18th Ann. Rept. Storrs Agric. Exp. Sta., 1906, 179; *Bacillus pruchii* Buchanan and Hammer, Iowa Agric. Exp. Sta. Res. Bull. No. 22, 1915, 276; Bergey et al., Manual, 1st ed., 1923, 322.) Named for M. J. Prucha, American bacteriologist.

Rods: Variable in size, with club-shaped ends. Motile, with peritrichous

flagella. Spores central, oval, not swelling rods. Gram-positive.

Gelatin: Rapid, stratiform liquefaction. Reddish-yellow sediment.

Agar surface colonies (anaerobic): Round, flat, white, smooth, opaque.

Agar slant (anaerobic): Luxuriant, white, viscid.

Broth: Turbid, with flocculent pellicle and gray viscous sediment.

Litmus milk: Acid; slowly coagulated, becoming slimy yellow.

Potato: Thin, brownish, spreading.

Indole not formed.

Nitrites not produced from nitrates.

Acid but no gas from glucose.

Coagulated albumin not recorded.

Blood serum not liquefied.

Non-pathogenic.

Optimum temperature 30°C. Grows well between 20°C and 37°C.

Anaerobic.

Source: From slimy milk.

Habitat: Not determined, other than this source.

23. **Clostridium cylindrosporum** Barker and Beck. (Jour. Biol. Chem., *141*, 1941, 3.) Named from the characteristic spore morphology.

Rods: 1.0 by 4.0 to 7.0 microns, straight. Motile with peritrichous flagella. Spores elongate to cylindrical, 1.0 to 1.1 by 1.7 to 3.0 microns, central, subterminal to terminal, with little or no swelling of rods. Gram-negative.

Iron-gelatin (Spray): No growth.

Deep plain agar: No growth.

Deep uric acid agar colonies: Whitish, compact, lobate, 1 to 2 mm in diameter, with irregular edges, surrounded by a zone of precipitated ammonium ureate which gradually disappears.

Plain broth: No growth.

Glucose broth: No growth.

Iron-milk (Spray): No growth.

Indole not recorded (probably negative).

Nitrites not recorded (probably negative).

Glucose not fermented.

Carbohydrates not fermented.

Cellulose not fermented.

Coagulated albumin not liquefied.

Blood serum not liquefied.

Brain medium not digested or blackened.

Pathogenicity not recorded (probably non-pathogenic).

Optimum temperature about 35°C.

Optimum reaction about pH 7.5; lower limit for growth pH 6.5.

Anaerobic.

Distinctive characters: Requires uric acid, or certain other purines, as a primary source of carbon and energy. The purines are converted into ammonia, CO_2, acetic acid and a little glycine. This organism is physiologically similar to *Clostridium acidi-urici*, but may be readily distinguished from the latter by its morphology.

Source: A single strain isolated from soil.

Habitat: Probably soil, although only this single isolation is recorded.

24. **Clostridium perfringens** (Veillon and Zuber) Holland.* *Clostridium perfringens* Type A, Wilsdon. (*Bacillus aerogenes capsulatus* Welch and Nuttall, Johns Hopkins Hosp. Bull. *3*, 1892, 81 (*Bacillus capsulatus aerogenes* Lehmann and Neumann, Bakt. Diag., 2 Aufl., *2*, 1899, 327); *Bacillus phlegmones emphysematosae* Fraenkel, Ueber Gasphleg-

* Because of use of the species name *perfringens* by the Permanent Standards Commission of the Health Organization of the League of Nations (Report of the Permanent Commission on Biological Standardization, London, June 23, 1931), the use of this name has been continued although it is preceded by a valid binomial (*Bacillus emphysematosus* Kruse).

monen, Leipzig, 1893, 47; *Bacillus emphysematosus* Kruse, in Flügge, Die Mikroorg., 3 Aufl., *2*, 1896, 242; *Bacterium aerogenes capsulatus* Chester, Ann. Rept. Del. Col. Agr. Exp. Sta., *9*, 1897, 125; *Bacterium emphysematosus* Chester, *ibid.*, 126; *Bacillus emphysematis vaginae* Lindenthal, Wien. klin. Wchnschr., *10*, 1897, 42; *Bacillus perfringens* Veillon and Zuber, Arch. Méd. Expt. et Anat. Path., *10*, 1898, 539; *Bacillus capsulatus anaerobius* and *Bacillus capsulatus aerogenes* Binaghi, Cent. f. Bakt., II Abt., *4*, 1898, 920; *Granulobacillus saccharobutyricus immobilis liquefaciens* Schattenfroh and Grassberger, Cent. f. Bakt., II Abt., *5*, 1899, 702 (*Granulobacillus immobilis* Schattenfroh and Grassberger, Arch. f. Hyg., *37*, 1900, 68; *Bacillus amylobacter immobilis* Gratz and Vas, Cent. f. Bakt., II Abt., *41*, 1914, 509); *Bacterium welchii* Migula, *ibid.*, 392; *Bacillus welchii* Lehmann and Neumann, Bakt. Diag., 4 Aufl., *2*, 1907, 457; *Bacillus butyricus asporogenes immobilis* Rocchi, Cent. f. Bakt., I Abt., Orig., *60*, 1911, 580; probably *Bacillus multiformis* Distaso, Cent. f. Bakt., I Abt., Orig., *59*, 1911, 101 (*Bacteroides multiformis* Bergey et al., Manual, 1st ed., 1923, 263; *Cillobacterium multiforme* Prévot, Ann. Inst. Past., *60*, 1938, 297; not *Bacillus multiformis* van Senus, Inaug. Diss., Leiden, 1890, (?), quoted from Herfeldt, Cent. f. Bakt., II Abt., *1*, 1895, 117); *Bacillus aerogenes-capsulatus* Holland, Jour. Bact., *5*, 1920, 217; *Clostridium aerogenes-capsulatum* Holland, *ibid.*, 217; *Bacillus phlegmones-emphysematosae* Holland, *ibid.*, 219; *Clostridium phlegmones-emphysematosae* Holland, *ibid.*, 219; *Clostridium phlegmones emphysematosae* Holland, *ibid.*, 222; *Clostridium welchii* Holland, *ibid.*, 221; *Clostridium perfringens* Holland, *ibid.*, 219; *Welchillus aerogenes* Heller, Jour. Bact., *7*, 1922, 6; *Butyribacillus immobilis-liquefaciens* Heller, *ibid.*, 18; *Bacillus welchii* Type A Wilsdon, Univ. Cambridge, Inst. Animal Path., 2nd Rept. of Dir., 1931, 72; *Clostridium saccharobutyricum liquefaciens* van Beynum and Pette, Cent. f. Bakt., II Abt., *93*, 1935–36, 205; *Welchia perfringens* Prévot, Ann. Inst. Past., *61*, 1938, 78.) Latinized, very fringed.

Related varieties: *Clostridium egens* Bergey et al., Manual, 1st ed., 1923, 324 (*Bacillus egens* Stoddard, Jour. Exp. Med., *29*, 1919, 187; *Stoddardillus egens* Heller, Jour. Bact., *7*, 1922, 6; *Clostridium perfringens* var. *egens* Hauduroy et al., Dict. d. Bact. Path., 1937, 124; *Welchia perfringens* var. *egens* Prévot, Ann. Inst. Past., *61*, 1938, 78).

Clostridium perfringens Type B, Wilsdon. (Bacillus of lamb dysentery, Dalling, Jour. Path. and Bact., *28*, 1925, 536, and *ibid.*, *29*, 1926, 316; L. D. Bacillus, Dalling, Handbook Ann. Congr. Nat. Vet. Med. Assoc., Gt. Britain and Ireland, 1928, 56; *Bacillus welchii* Type B, Wilsdon, Univ. Cambridge, Inst. Animal Path., 2nd Rept. of Dir., 1931, 73; *Clostridium welchii* (Type *agni*) Glenny et al., Jour. Path. and Bact., *37*, 1933, 53; *Bacillus agni* Weinberg et al., Les Mic. Anaér., 1937, 233; *Welchia agni* Prévot, Ann. Inst. Past., *61*, 1938, 78.)

Clostridium perfringens Type C, Wilsdon. (*Bacillus paludis* McEwen, Jour. Compar. Path. and Ther., *43*, 1930, 1; *Bacillus welchii* Type C, Wilsdon, Univ. Cambridge, Inst. Animal Path., 2nd Rept. of Dir., 1931, 73; *Welchia agni* var. *paludis* Prévot, Ann. Inst. Past., *61*, 1938, 78; *Welchia paludis* Prévot, Man. d. Class., etc., 1940, 217.)

Clostridium perfringens Type D, Wilsdon. (*Bacillus welchii* Type D, Wilsdon, Univ. Cambridge, Inst. Animal Path., 2nd Rept. of Dir., 1931, 74; *Bacillus ovitoxicus* Bennetts, Austral. Inst. Sci. and Indus., Bull. No. 57, 1932, 5, and Vet. Jour., *88*, 1932, 250; *Welchia agni* var. *ovitoxicus* Prévot, Ann. Inst. Past., *61*, 1938, 78; *Clostridium ovitoxicus* Spray, in Manual, 5th ed., 1939, 773; *Welchia ovitoxicus* Prévot, Man. d. Class., etc., 1940, 217.)

Probably related (or possibly identical) varieties: Bacille du rhumatisme,

Achalme, Compt. rend. Soc. Biol., Paris, *43*, 1891, 651, and Ann. Inst. Past., *11*, 1897, 848 (Bacille and bacterium d'Achalme, Thiroloix, Compt. rend. Soc. Biol., Paris, *49*, 1897, 268; *Bacillus achalmei* Neveu-Lemaire, Précis Parasitol. Hum., 5th ed., 1921, 24); *Bacillus emphysematis maligni* Wicklein, Arch. f. Path. Anat. u. Physiol., *125*, 1891, 91; *Bacillus cadaveris* Sternberg, Researches relating to the etiology and prevention of yellow fever, Washington, 1891, 212 (*Bacterium cadaveris* Migula, Syst. d. Bakt., *2*, 1900, 510; not *Bacillus cadaveris* Klein, Cent. f. Bakt., I Abt., *25*, 1899, 279; not *Clostridium cadaveris* Sternberg, *loc. cit.*, 213; not *Bacillus cadaveris* Migula, *loc. cit.*, 646); *Bacillus cadaveris butyricus* Buday, Cent. f. Bakt., I Abt., *24*, 1898, 374 (*Bacillus budayi* and *Bacterium cadaveris butyricum* LeBlaye and Guggenheim, Man. Prat. de Diag. Bact., 1914, 378; *Eubacterium cadaveris* Prévot, Ann. Inst. Past., *60*, 1938, 295).

Bacillus zoodysenteriae Weinberg et al., Les Mic. Anaér., 1937, 256 (*Bacillus zoodysenteriae hungaricus* Detre, Cent. f. Bakt., I Abt., Orig., *104*, 1927, 251; *Welchia perfringens* var. *zoodysenteriae* Prévot, Ann. Inst. Past., *61*, 1938, 78).

Clostridium perfringens var. *anaerogenes* Hauduroy et al., Dict. d. Bact. Path., 1937, 122 (Unnamed species of Grootten, Compt. rend. Soc. Biol., Paris, *100*, 1929, 499).

Rods: Short, thick, 1.0 to 1.5 by 4.0 to 8.0 microns, occurring singly and in pairs, less frequently in short chains. Non-motile. Spores oval, central to excentric, not swelling rods. Encapsulated. Gram-positive.

Gelatin: Liquefied and blackened.

Agar surface colonies (anaerobic): Circular, moist, slightly raised, opaque center, entire.

Broth: Turbid; peptolytic. Clearing with viscid sediment.

Litmus milk: Acid, coagulated. Clot torn with profuse gas formation, but not digested.

Potato: Thin, grayish-white streak; gas in subtended liquid.

Indole not formed.

Nitrites produced from nitrates.

Acid and gas from glucose, fructose, galactose, mannose, maltose, lactose, sucrose, xylose, trehalose, raffinose, starch, glycogen and inositol. Mannitol not fermented. Salicin rarely fermented. Action on inulin and glycerol variable.

Coagulated albumin not liquefied.

Blood serum not liquefied.

Brain medium not blackened or digested.

Egg-meat: Profuse gas production in 8 hours. The meat is reddened and the liquid becomes turbid. No digestion.

Pathogenic for guinea pig, pigeon and mouse. Produces an exotoxin for which an antitoxin can be prepared.

Optimum temperature 35°C to 37°C. Can grow at 50°C.

Anaerobic.

Distinctive characters: Stormy fermentation of milk, combined with non-motility.

Source: Gaseous gangrene, feces, milk and soil.

Habitat: Widely distributed in feces, sewage and soil.

25. **Clostridium sphenoides** (Bulloch et al.) Bergey et al. (*Bacillus sphenoides* Bulloch, Bulloch, Douglas, Henry, McIntosh, O'Brien, Robertson and Wolf, Med. Res. Counc., Spec. Rept. Ser. No. 39, 1919, 43; *Douglasillus sphenoides* Heller, Jour. Bact., *7*, 1922, 5; Bergey et al., Manual, 1st ed., 1923, 331; *Plectridium sphenoides* Prévot, Ann. Inst. Past., *61*, 1938, 88.) From Greek, wedge-shaped.

Described from Bulloch et al., *loc. cit.*, as amplified by Hall, Jour. Inf. Dis., *30*, 1922, 502.

Rods: Small, fusiform in vegetative state, occurring singly, in pairs and occasionally in short chains. Sporulating cells cuneate. Motile. Spores spherical, subterminal, becoming terminal on

maturation, swelling rods. Gram-positive only in young cultures.

Gelatin: Not liquefied.

Agar surface colonies (anaerobic): Circular, or slightly irregular, entire.

Blood agar surface colonies (anaerobic): Minute dew-drops, becoming whitish, opaque. Blood is hemolyzed.

Deep agar colonies: Minute, opaque, smooth disks.

Broth: Turbid.

Litmus milk: Acid; slowly and softly coagulated. Clot not digested.

Indole not formed (indole formed by Tholby strain, Stanley and Spray, Jour. Bact., *41*, 1941, 256).

Nitrites produced from nitrates.

Acid and gas from glucose, galactose, maltose, lactose and salicin. Inulin, glycerol and dulcitol not fermented. Strains are apparently variable on mannitol, sucrose, dextrin and starch.

Coagulated albumin not liquefied.

Blood serum not liquefied.

Brain medium not blackened or digested.

Non-pathogenic for guinea pig and rabbit.

Optimum temperature not determined. Grows well at 30°C to 37°C.

Anaerobic.

Source: From gangrenous war wounds.

Habitat: Not determined, other than this source.

26. **Clostridium innominatum** Prévot. (Bacillus E, Adamson, Jour. Path. and Bact., *22*, 1918–19, 391; Prévot, Ann. Inst. Past., *61*, 1938, 85.) From Latin, remaining unnamed.

Rods: Very small, thick, tapering at one or both ends, occurring singly, paired, in chains and filaments. Involution forms abundant on glucose agar. Motile. Spores small, spherical, subterminal, swelling rods. Gram-positive, quickly becoming Gram-negative.

Gelatin: Not liquefied.

Glucose agar surface colonies (anaerobic): Two forms are produced: 1) Circular, entire edge, opaque; 2) Diffuse, spreading, irregular and translucent.

Plain agar surface colonies (anaerobic): Small, circular, entire edge, whitish-translucent, becoming opaque-yellowish with age.

Plain broth: Moderate turbidity, clearing by sedimentation in 3 to 4 days.

Glucose broth: More abundant turbidity and slight gas production.

Milk: Slowly acidified but not clotted. No further change.

Glucose, maltose, lactose and mannitol fermented with acid and gas.

Sucrose not fermented.

Coagulated albumin: Not digested or blackened.

Meat medium: Not digested or blackened.

Blood serum: Not digested or blackened.

Brain medium: Not digested or blackened.

Non-pathogenic (Prévot, *loc. cit.*).

Grows well at 37°C.

Anaerobic.

Source: From septic and gangrenous war wounds.

Habitat: Not determined, other than this source.

27. **Clostridium filiforme** Bergey et al. (*Bacillus regularis filiformis* Debono, Cent. f. Bakt., I Abt., Orig., *62*, 1912, 234; Bergey et al., Manual, 1st ed., 1923, 331.) From Latin, thread-like.

Rods: 0.5 to 0.8 by 3.0 to 5.0 microns, slender, occurring singly, in pairs, in chains and filaments. Non-motile. Spores very small, spherical, subterminal, or occasionally terminal, not swelling rods. Gram-positive.

Gelatin: Not liquefied.

Deep gelatin colonies: Small, gray, filamentous.

Deep agar colonies: Irregular, gray, translucent, filamentous.

Broth: Uniform turbidity.

Litmus milk: Acid, but no further change.

Potato: Gray, filamentous; substance not digested.

Acid and gas from glucose and lactose. Acid only from sucrose and dulcitol. Starch not fermented.

Coagulated albumin not liquefied.

Grows in gelatin at 22°C.

Anaerobic.

Source: From human feces.

Habitat: Not determined, other than this source.

28. **Clostridium sartagoformum** Partansky and Henry. (Jour. Bact., *30*, 1935, 570.) From Latin, shaped like a frying-pan.

Rods: 0.3 to 0.5 by 3.5 to 6.0 microns. Slender, curved, with rounded ends, occurring singly. Motile. Spores oval, terminal, swelling rods. Gram-positive.

Gelatin: Not liquefied.

Agar surface colonies (anaerobic): Convex, discrete, circular, transparent to white and opaque. Surface moist and smooth.

Blood agar not hemolyzed.

Deep agar colonies: Regular, lenticular, smooth.

Broth: Clear; no growth.

Glucose broth: Turbid, with gas bubbles.

Litmus milk: Acid; slowly coagulated, with some gas formation. Clot not digested.

Potato: Very scant growth. No gas in surrounding liquid.

Indole not formed.

Nitrites not produced from nitrates.

Acid and gas from xylose, glucose, fructose, galactose, sucrose, lactose, maltose, raffinose, inulin, salicin, mannitol, acetate and butyrate. Starch, ethanol, glycerol and dulcitol not fermented.

Coagulated albumin not liquefied.

Blood serum not liquefied. Scant growth.

Brain medium not blackened or digested. Some gas is formed.

Optimum temperature 37°C.

Anaerobic.

Distinctive character: Ferments sulfite waste liquor in 40 per cent concentration, forming butyric and acetic acids, H_2 and CO_2.

Source: From garden soil and from stream and lake mud.

Habitat: Not recorded; obviously soil. Distribution undetermined.

29. **Clostridium paraputrificum** (Bienstock) Snyder. (Art V, Bienstock, Fortschr. d. Med., *1*, 1883, 612; *Bacillus diapthirus* Trevisan, I generi e le specie delle Batteriacee, 1889, 15; *Bacillus paraputrificus* Bienstock, Ann. Inst. Past., *20*, 1906, 413, and Strassburger Med. Zeit., *3*, 1906, 111; *Bacillus paraputrificus coli* Henry, Brit. Med. Jour., *1*, 1917, 763; *Tissierillus paraputrificus* Heller, Jour. Bact., *7*, 1922, 27; Snyder, Jour. Bact., *32*, 1936, 401; *Plectridium paraputrificum* Prévot, Man. d. Class., etc., 1940, 160.) From Latin, also putrefying.

Probable synonyms: Köpfchenbakterien, Escherich, Fortschr. d. Med., *8*, 1885, 515; Bacillus No. 3, Rodella, Ztschr. f. Hyg., *39*, 1902, 209 (*Plectridium fluxum* Prévot, Ann. Inst. Past., *61*, 1938, 87); Art XI, Hibler, Cent. f. Bakt., I Abt., *25*, 1899, 516 (Art IX, Hibler, Untersuch. ü. d. Path. Anaer., 1908, 3 and 407; *Plectridium nonum* Prévot, Ann. Inst. Past., *61*, 1938, 88); Anaerobe b, Dalyell, Jour. Path. and Bact., *19*, 1914–15, 281; *Bacillus innutritus* Kleinschmidt, Monatschr. f. Kinderheilkunde, *62*, 1934, 18 (*Palmula innutrita* Prévot, Ann. Inst. Past., *61*, 1938, 89; *Acuformis innutritus* Prévot, Man. d. Class., etc., 1940, 165).

Described from Hall and Snyder, Jour. Bact., *28*, 1934, 181.

Rods: 0.3 to 0.5 by 2.0 to 6.0 microns. Straight or slightly curved, single, in pairs, or in short chains. Ends rounded. Motile with peritrichous flagella. Spores oval, terminal, swelling rods. Gram-positive.

Gelatin: Not liquefied. Gas is formed.

Blood agar surface colonies (anaerobic): Delicate, irregular, round-topped dewdrops. Non-hemolytic.

Deep agar colonies: Small, irregular, opaque, dense, cottony masses. Gas is formed.

Broth: Diffuse turbidity.

Milk: Usually coagulated in from 6 to 10 days. Abundant gas, but no peptonization.

Indole is not formed.

Acid and gas from glucose, fructose, galactose, maltose, lactose, sucrose, raffinose, dextrin, soluble starch, amygdalin and salicin. Xylose, inulin, mannitol and glycerol not fermented.

Coagulated albumin not liquefied.

Blood serum not liquefied or discolored.

Brain medium not blackened or digested. Non-proteolytic.

Non-pathogenic for guinea pig and rabbit.

Grows well at 37°C.

Anaerobic.

Source: Feces, gaseous gangrene, and postmortem fluid and tissue cultures.

Habitat: Undetermined, other than these sources. Evidently occurs commonly in intestinal canal of human beings.

30. **Clostridium cochlearium** (Bulloch et al.) Bergey et al. (Bacillus Type IIIc, McIntosh, Med. Res. Counc., Spec. Rept. Ser. No. 12, 1917, 20; *Bacillus cochlearius* Bulloch, Bulloch, Douglas, Henry, McIntosh, O'Brien, Robertson and Wolf, Med. Res. Counc., Spec. Rept. Ser. No. 39, 1919, 40; *Flemingillus cochlearius* Heller, Jour. Bact., 7, 1922, 5; Bergey et al., Manual, 1st ed., 1923, 333; *Plectridium cochlearium* Prévot, Ann. Inst. Past., *61*, 1938, 88; *Plectridium incertum* Prévot, *idem.*) From Latin, spoon-shaped.

Rods: Slender, straight, occurring chiefly singly, or infrequently in pairs and in short chains. Motile with peritrichous flagella. Spores oval, terminal, swelling rods. Weakly Gram-positive.

Gelatin: Not liquefied.

Agar surface colonies (anaerobic): Circular, clear, entire, or with crenated edge.

Deep agar colonies: Lenticular, entire.

Broth: Turbid.

Litmus milk: Unchanged.

Glucose not fermented.

Carbohydrates not fermented.

Coagulated albumin not liquefied.

Blood serum not liquefied.

Brain medium not blackened or digested.

Meat medium: Slightly reddened. Not blackened or digested. Little gas of non-putrefactive odor.

Non-pathogenic.

Optimum temperature 30°C to 35°C.

Anaerobic.

Source: From human war wounds and septic infections.

Habitat: Not determined, other than these sources. Probably occurs in soil.

31. **Clostridium kluyveri** Barker and Taha. (Jour. Bact., *43*, 1942, 347.) Named for A. J. Kluyver, in whose laboratory the organism was discovered.

Rods: 0.9 to 1.1 by 3.0 to 11.0 microns. Straight to slightly curved; usually single, but also paired and occasionally in long chains. Motile with peritrichous flagella. Spores oval, terminal, swelling rods. Generally Gram-negative; some strains weakly Gram-positive when young.

Iron-gelatin (Spray): No growth.

Surface agar colonies (anaerobic): Growth slow and restricted by residual traces of oxygen. Rough and smooth colonies are produced.

Deep agar colonies (yeast autolysate and C_2H_5OH): Small colonies (1 to 3 mm) after 2 to 3 days; two types are formed: a) fluffy spheres with dense nuclear center and filamentous periphery; b) compact, lenticular colonies. Little gas is formed.

Plain broth: No growth.

Glucose broth: No growth.

Milk or iron-milk (Spray): No growth.

Indole not recorded (probably negative).

Nitrites not recorded (probably negative).

Glucose not fermented.

Carbohydrates not fermented.

Cellulose not fermented.

Coagulated albumin not liquefied.

Blood serum not liquefied.

Brain medium not digested or blackened.

Probably non-pathogenic.

Optimum temperature about 34°C. Grows between 19°C and 37°C.

Optimum reaction about pH 6.8. Range for growth pH 6.0 to 7.5.

Anaerobic.

Distinctive characters: Large size of cells, and slow growth, accompanied by non-putrefactive odor of caproic acid and of higher alcohols. Growth is exceptionally favored by synergistic association with *Methanobacterium omelianskii*. In pure culture a high concentration of yeast autolysate is required. Caproic acid is formed from ethyl alcohol.

Source: From black mud of fresh water and marine origin.

Habitat: Not determined, other than these sources. Evidently widely dispersed in nature.

32. **Clostridium acidiurici** (Liebert) Barker. (*Bacillus acidi urici* Liebert, Koninkl. Akad. v. Wetensch., Proc. Sect. Sci., Amsterdam, *12*, 1909, 55; Barker, Jour. Bact., *36*, 1938, 323.) Named from its characteristic ability to ferment uric acid.

Rods: 0.5 to 0.7 by 2.5 to 4.0 microns; straight. Motile with peritrichous flagella. Spores oval, terminal, swelling rods. Most strains Gram-negative. A few strains weakly Gram-positive, quickly becoming Gram-negative.

Iron-gelatin (Spray): No growth.

Deep plain agar: No growth.

Deep uric acid agar colonies: Whitish, compact, lobate, 1 to 2 mm in diameter, with irregular edge; surrounded by a temporary zone of precipitated ammonium ureate which gradually disappears.

Surface uric acid agar colonies (anaerobic): Variable with strain and with moisture of medium. Colonies 1 to 2 mm in diameter, opaque, white, raised, round, smooth edge, with concentric surface markings, and of rubbery consistency. Other colonies may be very thin, soft, transparent, with fimbriate projections, spreading to cover almost the entire plate. Intermediate colony types also observed.

Plain broth: No growth.

Glucose broth: No growth.

Iron-milk (Spray): No growth.

Indole not recorded (probably negative).

Nitrites not recorded (probably negative).

Glucose not fermented.

Carbohydrates not fermented.

Cellulose not fermented.

Coagulated albumin not liquefied

Blood serum not liquefied.

Brain medium not digested or blackened.

Probably non-pathogenic.

Optimum temperature about 35°C.

Optimum reaction about pH 7.5; lower limit for growth about pH 6.5.

Anaerobic.

Distinctive characters: Requires uric acid, or certain other purines, as a primary source of carbon and energy. The purines are converted mainly into ammonia, CO_2 and acetic acid. During growth the medium tends to become alkaline (pH 8.0 to 8.5); there is no visible evolution of gas.

Source: From soils of diverse origin.

Habitat: Evidently widely dispersed in soils. Present in fecal material of yellow-shafted flicker (*Colaptes auratus*).

33. **Clostridium capitovale** (Snyder and Hall) Snyder. (*Bacillus capitovalis* Snyder and Hall, Cent. f. Bakt., I Abt., Orig., *135*, 1935, 290; *Clostridium capitovalis* Snyder, Jour. Bact., *32*, 1936, 401; *Plectridium capitovalis* Prévot, Ann. Inst. Past., *61*, 1938, 87.) From Latin, oval-headed.

Rods: 0.5 to 0.8 by 2.0 to 2.5 microns. Slender, commonly curved, with rounded ends, occurring singly, in pairs, and rarely in short chains. Motile with long peri-

trichous flagella. Spores oval, terminal, swelling rods. Gram-positive.

Gelatin: Liquefied.

Blood agar surface colonies (anaerobic): Tiny, transparent, round or irregular dew-drops, becoming opaque. Non-hemolytic.

Deep agar colonies: Small, opaque, lenticular to heart-shaped.

Tryptone broth: Turbid. Gas is formed.

Milk: Often, but not invariably, clotted. Acid is formed. Clot, when formed, is not digested.

Indole not formed.

Nitrites not produced from nitrates.

Acid and gas from glucose, fructose and galactose. Maltose, lactose, sucrose, raffinose, xylose, inulin, dextrin, starch, cellulose, amygdalin, salicin, mannitol and glycerol not fermented.

Coagulated albumin liquefied.

Blood serum slowly softened and partially liquefied. Not blackened. Mildly proteolytic.

Brain medium is blackened; slightly softened, but not conspicuously liquefied.

Pathogenicity: Guinea pig may show slight subcutaneous edema; usually no effect. Non-pathogenic for rabbit.

Grows at 37°C.

Anaerobic.

Source: Human feces, gaseous gangrene and septicemia.

Habitat: Not determined, other than these sources.

34. **Clostridium parabifermentans** *comb. nov.* (*Bacillus parabifermentans sporogenes* de Gasperi, Compt. rend. Soc. Biol., Paris, *67*, 1909, 492.) From Greek, *para*, near, and Latin, *bis*, twice, and *fermentum*, a ferment.

Rods: 0.5 to 0.7 by 4.0 to 5.0 microns, occurring singly, in pairs and in chains of 3 to 5 cells. Motile. Spores oval, terminal, swelling rods. Gram-positive.

Glucose gelatin: Rapid growth with liquefaction.

Deep glucose agar colonies: Lenticular, regular, opaque, whitish. Agar disrupted by considerable gas of putrefactive odor.

Glucose broth: Abundant growth with uniform turbidity and with viscous sediment.

Milk: Acidified but not coagulated. Casein slowly precipitated with slow, but complete, digestion.

Indole formed in trace.

Glucose, lactose and sucrose fermented to acids. (Gas not recorded.) Starch is not fermented.

Coagulated albumin actively liquefied.

Non-pathogenic for mouse.

Grows between 22°C and 37°C.

Anaerobic.

Source: From putrefying game (pheasant and guinea-fowl).

Habitat: Undetermined, other than this source.

35. **Clostridium ovalare** Bergey et al. (*Bacillus putrificus ovalaris* Debono, Cent. f. Bakt., I Abt., Orig., *62*, 1912, 231; Bergey et al., Manual, 1st ed., 1923, 336; *Plectridium ovalaris* Prévot, Ann. Inst. Past., *61*, 1938, 88.) From Latin, oval.

Rods: 0.3 to 0.4 by 6.0 to 8.0 microns, straight or curving, ends rounded, occurring singly, in pairs and in short chains. Motile. Spores oval, terminal, swelling rods. Gram-positive.

Gelatin: Rapidly liquefied.

Deep glucose agar colonies: Small, globular, entire, becoming brownish. Scant gas is formed.

Broth: Turbid.

Litmus milk: Acid, peptonized without coagulation.

Indole not formed.

Acid and scant gas from glucose and lactose. Acid only from sucrose. Dulcitol not fermented.

Coagulated albumin rendered transparent, then slowly peptonized, with a putrefactive odor.

Grows at 22°C and at 37°C.

Anaerobic.

Source: Originally from putrid meat, later from feces.

Habitat: Not determined, other than these sources.

36. **Clostridium zoogleicum** Bergey et al. (*Bacillus sporogenes zoogleicus* Distaso, Cent. f. Bakt., I Abt., Orig., *59*, 1911, 99; Bergey et al., Manual, 1st ed., 1923, 335.) From Greek, zoogleal.

Rods: Fairly long, occurring singly, in pairs and in short chains. Motile. Spores large, oval, terminal, swelling rods. Gram-positive.

Gelatin: Growth and liquefaction not recorded.

Deep agar colonies: Small, gray, slightly opaque, becoming heart-shaped. Gas is not formed.

Broth: Turbid, then clearing with zoogleal sediment.

Litmus milk: Slowly coagulated, then digested. Litmus reduced.

Indole is formed in trace.

Acid but no gas from glucose. Lactose and sucrose not fermented.

Coagulated albumin liquefied, leaving a clear fluid and zoogleal sediment.

Grows at 37°C.

Anaerobic.

Source: From human feces.

Habitat: Undetermined, other than this source.

37. **Clostridium thermosaccharolyticum** McClung. (Jour. Bact., *29*, 1935, 200; *Terminosporus thermosaccharolyticus* Prévot, Ann. Inst. Past, *61*, 1938, 86.) From Greek, heat, and sugar-digesting.

Rods: 0.4 to 0.7 by 3.5 to 7.5 microns, slender, granulated, occurring singly and in pairs, not in chains. Motile with peritrichous flagella. Spores spherical, terminal, swelling rods. Gram-negative.

Gelatin: Not liquefied.

Pea-infusion agar surface colonies (anaerobic): Granular, grayish-white, raised center, with feathery edges.

Deep glucose-tryptone agar colonies: Small, lenticular, smooth.

Liver-infusion broth over liver meat: Turbidity and gas.

Litmus milk: Litmus reduced. Acid and slow but firm coagulation; coagulum split with gas. Clot not digested.

Indole not formed.

Nitrites not produced from nitrates.

Cellulose not fermented.

Acid and gas from arabinose, fructose, galactose, glucose, mannose, xylose, cellobiose, lactose, maltose, sucrose, trehalose, dextrin, glycogen, corn-starch, amygdalin, esculin, α-methyl glucoside and salicin. Raffinose weakly fermented. Rhamnose, inulin, pectin, erythritol, inositol, mannitol, glycerol, quercitol and Ca-lactate not fermented.

Coagulated albumin not liquefied.

Blood serum not liquefied.

Brain medium not blackened or digested.

Meat-medium not blackened or digested.

Non-pathogenic on feeding to white rat, or by injection into rabbit.

Optimum temperature 55°C to 62°C. Thermophilic.

Anaerobic.

Source: From hard-swell of canned goods, and from soil.

Habitat: Not determined, other than these sources.

38. **Clostridium caloritolerans** Meyer and Lang. (Jour. Inf. Dis., *39*, 1926, 321; *Plectridium caloritolerans* Prévot, Ann. Inst. Past., *61*, 1938, 87.) From Latin, heat-enduring.

Rods: 0.5 to 0.8 by 8.0 to 10.0 microns, with rounded ends, occurring singly, in pairs, in chains and in curved filaments. Motile with peritrichous flagella. Spores spherical or pear-shaped, terminal, swelling rods. Gram-positive.

Gelatin: Not liquefied.

Glucose blood agar surface colonies (anaerobic): Small, flat, grayish, rhizoidal. Non-hemolytic.

Deep liver agar colonies: Small, flat, transparent disks with large polar tufts. Some colonies become fluffy.

Broth: Slight turbidity.

Glucose broth: Abundant turbidity,

with clearing by sedimentation. Gas is formed.

Brom cresol purple milk: No change.

Indole not formed.

Acid and gas from glucose, galactose and maltose. Fructose feebly fermented. Lactose, sucrose, raffinose, inulin, salicin, mannitol, inositol and glycerol not fermented.

Coagulated albumin not liquefied.

Blood serum not liquefied.

Brain medium not blackened or digested.

Beef-heart mash medium: Reddened; not blackened or digested.

Non-pathogenic for mouse, guinea pig and rabbit.

Optimum temperature not determined. Grows at 37°C.

Anaerobic.

Source: From an old culture of *Clostridium parabotulinum* Type A.

Habitat: Not determined, other than this single isolation.

39. **Clostridium tetanoides** (Adamson) Hauduroy et al. (Unnamed anaerobe, Adamson and Cutler, Lancet, *1*, 1917, 688; *Bacillus tetanoides* (*A*) Adamson, Jour. Path. and Bact., *22*, 1918–19, 382; Hauduroy et al., Dict. d. Bact. Path., 1937, 140; *Palmula macrospora* Prévot, Ann. Inst. Past., *61*, 1938, 88; *Acuformis macrosporus* Prévot, Man. d. Class., etc., 1940, 166.) From Latin, tetanus-like.

Rods: 1.0 to 2.0 by 4.0 to 12.0 microns (averaging 1.0 to 1.5 by 6.0 to 7.0 microns), with rounded to slightly tapered ends, occurring singly, in pairs and in chains of 3 to 5 cells, but not in filaments. Motile only in young cultures. Spores large, spherical, terminal, swelling rods. Gram-positive in young cultures, soon becoming Gram-negative.

Gelatin: Not liquefied.

Glucose agar surface colonies (anaerobic): Circular, regular, opaque, bluish-gray, moist, shining, thick, raised. Surface flat, becoming conical in center with age. On moist medium showing radiating, dendritic branching. Growth becomes tenacious-mucoid.

Plain agar surface colonies (anaerobic): Confluent, becoming an opaque film. Isolated colonies circular to slightly irregular. Dendritic branching and mucoid tendency less evident than on glucose agar.

Glucose agar stab: Thick growth along stab, starting 0.5 cm below surface. No gas or splitting of medium.

Neutral-red glucose agar: Reduced to orange by transmitted, and greenish-fluorescent by reflected light.

Plain broth: Early slight turbidity, with clearing and mucoid sedimentation.

Glucose broth: Abundant turbidity and profuse mucoid sediment.

Milk: Slight and slowly increasing alkalinity, with slow separation of casein. No further change.

Indole: Trace formed in broth.

Glucose and maltose fermented with acid but no gas. Lactose, sucrose, mannitol, starch and cellulose not fermented.

Coagulated albumin: Not digested or blackened.

Meat medium: Not digested or blackened.

Blood serum: Not digested or blackened.

Brain medium: Not digested or blackened.

Non-pathogenic for guinea pig and rabbit.

Optimum temperature not recorded. Grows well at 37°C.

Anaerobic.

Source: From war wounds, from post-mortem blood culture, and from garden soil.

Habitat: Not determined, other than these sources.

40. **Clostridium tetani** (Flügge) Holland. (Tetanusbacillen and Tetanuserreger, Nicolaier, Deuts. Med. Wchnschr., *10*, 1884, 843; *Bacillus tetani* Flügge, Die Mikroorg., 2 Aufl., 1886, 274; *Pacinia nicolaieri* Trevisan, I generi e le specie delle Batteriacee, 1889, 23; *Plectridium*

tetani Fischer, Jahrb. f. Wissensch. Botanik, *27*, 1895, (147?); Holland, Jour. Bact., *5*, 1920, 220; *Nicollaierillus tetani* Heller, Jour. Bact., *7*, 1922, 7.) From *tetanus*, lockjaw.

Rods: 0.4 to 0.6 by 4.0 to 8.0 microns, rounded ends, occurring singly, in pairs, and often in long chains and filaments. Motile with peritrichous flagella. Spores spherical, terminal, swelling rods. Gram-positive.

Gelatin: Slowly liquefied and blackened.

Serum agar surface colonies (anaerobic): Small, transparent, villous to fimbriate margin.

Blood agar is hemolyzed.

Deep agar colonies: Fluffy, cottony spheres, usually without visible central nucleus.

Broth: Slightly turbid. Gas is formed. Some strains clear quickly by sedimentation.

Litmus milk: Slow precipitation of casein, or soft clotting. Clot slowly softened, but not definitely digested. Little gas is formed.

Indole is formed.

Nitrites not produced from nitrates.

Glucose not fermented.

Carbohydrates not fermented.

Coagulated albumin slowly liquefied.

Blood serum slowly softened, with feeble digestion.

Brain medium blackened and slowly digested. Not actively proteolytic.

Pathogenic and toxic. Forms a potent exotoxin for which an antitoxin is prepared. Toxin intensely toxic on injection but not on feeding.

Optimum temperature 37°C.

Anaerobic.

Source: Originally isolated from animals inoculated with garden soil extract. Frequently isolated from wounds in human tetanus.

Habitat: Common in soils, and in human and horse intestine and feces.

41. Clostridium lentoputrescens Hartsell and Rettger. (Bacillus der Eiweissfäulniss, Bienstock, Fortschr. d. Med., *1*, 1883, 614 (Art IV, Bienstock, *ibid.*, 612; Eiweissbacillus, Bienstock, Ztschr. f. klin. Med., *8*, 1884, 38); *Bacillus albuminis* Schroeter, in Cohn's Kryptogamen-Flora von Schlesien, *3*, 1, 1886, 162; *Bacillus putrificus coli* Flügge, Die Mikroorg., 2 Aufl., 1886, 303; *Pacinia putrifica* Trevisan, I generi e le specie delle Batteriacee, 1889, 23; *Bacillus putrificus* Bienstock, Ann. Inst. Past. *13*, 1899, 861; *Bacillus butyricus putrefaciens* Rodella, Ann. Inst. Past., *19* 1905, 804; *Putribacillus vulgaris* Orla-Jensen, Cent. f. Bakt., II Abt., *22*, 1909, 343; *Clostridium putrificum* Holland, Jour. Bact., *5*, 1920, 220; *Putrificus bienstocki* Heller, Jour. Bact., *7*, 1922, 8; *Bacillus putrificus* (*coli*) Lehmann and Neumann, Bakt. Diag., 7 Aufl., *2*, 1927, 661; Hartsell and Rettger, Jour. Bact., *27*, 1934, 39 and 497; *Plectridium putrificum* and *Plectridium putrificum* var. *lentoputrescens* Prévot, Ann. Inst. Past., *61*, 1938, 88.) From Latin, slowly made putrid.

Probable synonyms: *Bacillus radiatus* Lüderitz, Ztschr. f. Hyg., *5*, 1889, 149 (*Cornilia radiata* Trevisan, *loc. cit.*, 22; *Bacillus radiatus anaerobius* Hopffe, Ztschr. f. Infkrnkh. u. Hyg. Haust., *14*, 1913, 392); *Bacillus cadaveris sporogenes* (*anaerobicus*) Klein, Cent. f. Bakt., I Abt., *25*, 1899, 279 (*Bacillus cadaveris* Klein, *idem*; not *Bacillus cadaveris* Sternberg, Researches relating to the etiology and prevention of yellow fever, Washington, 1891, 212; not *Bacillus cadaveris* Migula, Syst. d. Bakt., *2*, 1900, 646; *Bacillus cadaveris sporogenes* Klein, *loc. cit.*, 284; *Plectridium cadaveris* Prévot, Ann. Inst. Past., *61*, 1938, 88); Art XIV, von Hibler, Untersuch. ü. d. Path. Anaer., 1908, 3 and 413; *Bacillus tetanoides* (*B*) Adamson, Jour. Bact. and Path., *22*, 1918–19, 388.

Hartsell and Rettger, *loc. cit.*, conclude that their organism differs very materially either from *Clostridium cochlearium* or from *Bacillus putrificus*, as described by Cunningham, Jour. Bact.,

24, 1932, 61, and, as it cannot be definitely related to any other anaerobic species (including the Eiweissbacillus, Bienstock, *loc. cit.*, *Bacillus putrificus coli* Flügge, *loc. cit.*, *Bacillus putrificus* Bienstock, *loc. cit.*, etc.), they propose the name of *Clostridium lentoputrescens* for this species.

Rods: 0.4 to 0.6 by 7.0 to 9.0 microns, with rounded ends, occurring singly, in pairs and in chains. Motile with peritrichous flagella. Spores spherical, terminal, swelling rods. Weakly Gram-positive, becoming Gram-negative.

Gelatin: Liquefied.

Agar surface colonies (anaerobic): Small, circular, flat, edge crenated to filamentous spreading. Develop a ground-glass appearance.

Deep agar colonies: Fluffy spheres with fibrils radiating from a central nucleus.

Blood agar is hemolyzed.

Litmus milk: Slow, soft coagulation or flocculent precipitation. Casein is slowly digested.

Indole is formed (Hall, Jour. Inf. Dis., *30*, 1922, 141). Not formed (Hartsell and Rettger, *loc. cit.*, 509).

Nitrites not produced from nitrates.

Hydrogen sulfide formed in egg-meat medium.

Carbohydrates not fermented. Glucose slightly attacked without distinct acid (Hartsell and Rettger, *loc. cit.*, 508).

Coagulated albumin slowly liquefied and blackened.

Blood serum is liquefied. Gas is formed.

Brain medium slowly blackened and digested.

Egg-meat medium: Slightly turbid liquid. Meat reddened in 7 to 10 days, then digested with a foul odor.

Non-pathogenic for white mouse, guinea pig and rabbit. Filtrate non-toxic on injection or feeding.

Grows well at 37°C.

Anaerobic.

Source: From putrefying meat.

Habitat: Intestinal canal of human. Widely dispersed in soil.

42. **Clostridium filamentosum** Bergey et al. (*Bacillus putrificus filamentosus* Distaso, Cent. f. Bakt., I Abt., Orig., *59*, 1911, 98; Bergey et al., Manual, 1st ed., 1923, 333; *Palmula filamentosa* Prévot, Ann. Inst. Past., *61*, 1938, 88; *Acuformis filamentosus* Prévot, Man. d. Class., etc., 1940, 165.) From Latin, filamentous.

Rods: Slender, occurring singly, in pairs and in chains. Motile. Spores spherical, or nearly so, terminal, swelling rods. Gram-positive.

Gelatin: Liquefied.

Deep glucose agar colonies: Delicate, cottony flocculi. Only a trace of gas formed.

Broth: Turbid.

Litmus milk: May or may not coagulate and digest slowly (variable).

Indole formed in scarcely detectable trace. Odor of scatol.

Glucose is feebly fermented, with little gas. Lactose and sucrose not fermented.

Coagulated albumin: Rendered transparent, then slowly liquefied.

Grows well at 37°C.

Anaerobic.

Source: From human feces.

Habitat: Not determined, other than this source.

43. **Clostridium tetanomorphum** (Bulloch et al.) Bergey et al. (*Bacillus pseudo-tetanus*, Type No. IX,—Tetanus-like Bacillus (Pseudotetanus Bacillus), McIntosh and Fildes, Med. Res. Counc., Spec. Rept. Ser. No. 12, 1917, 11 and 32; *Bacillus tetanomorphus* Bulloch et al., Med. Res. Counc., Spec. Rept. Ser. No. 39, 1919, 41; *Macintoshillus tetanomorphus* Heller, Jour. Bact., *7*, 1922, 5; Bergey et al., Manual, 1st ed., 1923, 330; *Plectridium tetanomorphum* Prévot, Ann. Inst. Past., *61*, 1938, 87.) From Greek, shaped like the tetanus organism.

Synonyms or possibly related species: *Bacillus pseudotetani* Migula, Syst. d. Bakt., *2*, 1900, 598 (Tetanusähnlicher Bacillus and Pseudotetanusbacillus, Tavel and Lanz, Mitteil. a. klin. Med. Inst. d. Schweiz, *1*, 1893, 162; *Bacillus taveli*

Chester, Man. Determ. Bact., 1901, 304; *Plectridium pseudotetanicum* Prévot, Ann. Inst. Past., *61*, 1938, 87; *Plectridium pseudo-tetanicum* Prévot, Man. d. Class., etc., 1940, 158); possibly identical with *Bacillus fragilis* Veillon and Zuber, Arch. d. Méd. Expt. et d'Anat. Path., *10*, 1898, 536 and *Bacillus ramosus* Veillon and Zuber, *ibid.*, 537.

Rods: Slender, with rounded ends, occurring singly and in pairs, not in chains. Motile with peritrichous flagella. Spores spherical, or nearly so, terminal, swelling rods. Gram-positive.

Gelatin: Not liquefied. Gelatin is liquefied (Hall, Jour. Inf. Dis., *30*, 1922, 501).

Agar surface colonies (anaerobic): Small, flat, irregularly circular, translucent, crenated.

Deep agar colonies: Small, opaque, irregular; not woolly or branched.

Agar slant (anaerobic): Grayish, translucent growth.

Broth: Turbid.

Litmus milk: Unchanged; or occasional slight reduction of litmus.

Acid and gas from glucose and maltose. Fructose, galactose, lactose, sucrose, salicin, inulin, mannitol and glycerol not fermented.

Coagulated albumin not liquefied.

Blood serum not liquefied.

Brain medium not blackened or digested.

Egg-meat medium: Slight gas formation in 48 hours. White crystals are deposited.

Non-pathogenic for guinea pig and rabbit.

Grows at 30°C and 37°C.

Anaerobic.

Source: From war wounds and from soil.

Habitat: Not determined other than these sources. Probably rather common in soil.

44. **Clostridium alcaligenes** Bergey et al. (*Bacillus anaërobicus alcaligenes* Debono, Cent. f. Bakt., I Abt., Orig., *62*, 1912, 232; Bergey et al., Manual, 1st ed., 1923, 331; *Palmula alcaligenes* Prévot, Ann. Inst. Past., *61*, 1938, 89; *Acuformis alcaligenes* Prévot, Man. d. Class., etc., 1940, 165.) From French *alcali*, alkali and Latin suffix, producing.

Rods: Long, slender, occurring singly, in pairs and in short chains. Non-motile. Spores spherical, terminal, swelling rods. Gram-positive.

Gelatin: Not liquefied.

Deep glucose agar colonies: Lenticular to irregular, or spherical, white, granular, entire.

Broth: Uniform turbidity. Fecal odor.

Milk: Alkaline; casein slowly precipitated, with yellowish supernatant fluid.

Indole is formed in abundance.

Acid and gas from glucose and lactose. Sucrose and dulcitol not fermented. Cultures have odor of valerianic acid.

Grows at 22°C and at 37°C.

Anaerobic.

Source: From human feces.

Habitat: Not determined, other than this source.

45. **Clostridium angulosum** (Distaso) Hauduroy et al. (*Bacillus angulosus* Distaso, Cent. f. Bakt., I Abt., Orig., *62*, 1912, 439; not *Bacillus angulosus* Garnier and Simon, Bull. et Mem. Soc. Méd. Hôp. Paris, *24*, 1907, 1034; *Bacteroides angulosus* Bergey et al., Manual, 1st ed., 1923, 260; Hauduroy et al., Dict. des Bact. Path., 1937, 91.) From Latin *angulosus*, having angles, hooked.

Rods: Short, thick, with rounded ends, occurring singly and in pairs. Long rods sometimes bent to form an obtuse angle. Encapsulated. Non-motile. Spores very small, spherical, terminal, slightly swelling rods. Gram stain not recorded.

Plain gelatin: No growth at 20°C or at 37°C.

Glucose gelatin: Grows well at 37°C. Growth cloudy at first, then clears and liquefies, with whitish, powdery precipitate.

Glucose agar deep colonies: Large,

angular, opaque, yellowish. Gas bubbles are formed.

Broth: Turbid.

Litmus milk: Acid and coagulated in 14 days.

Indole is formed.

Acid and gas from glucose, lactose and sucrose. Butyric acid is formed.

Coagulated albumin not liquefied. Odor of skatol.

Optimum temperature 37°C.

Anaerobic.

Distinctive character: Resembles the Bacille neigeux, Jungano, Compt. rend. Soc. Biol., Paris, *62*, 1907, 677, in form, but not in other respects.

Source: From human feces.

Habitat: Not determined, other than this source.

46. **Clostridium putrefaciens** (McBryde) Sturges and Drake. (*Bacillus putrefaciens* McBryde, U. S. D. A., Bur. An. Ind., Bull. 132, 1911, 6; Sturges and Drake, Jour. Bact., *14*, 1927, 175; *Palmula putrefaciens* Prévot, Ann. Inst. Past., *61*, 1938, 89; *Acuformis putrefaciens* Prévot, Man. d. Class., etc., 1940, 165.) From Latin, putrefying.

Description from McBryde (*loc. cit.*) and amplified from Sturges and Drake (*loc. cit.*).

Rods: 0.5 to 0.7 by 3.0 to 15.0 microns, rounded ends, occurring singly, in pairs, and in chains and filaments. Non-motile. Spores spherical, terminal, swelling rods. Gram-positive.

Gelatin: Liquefied.

Agar surface colonies (anaerobic): Small, filamentous.

Agar slant (anaerobic): Scanty, white, beaded, glistening growth.

Broth: Moderate turbidity. Heavy, flocculent sediment.

Litmus milk: Rennet coagulation, peptonized. Litmus reduced.

Indole not formed.

Nitrites not produced from nitrates.

Slight production of hydrogen sulfide.

Acid and gas from glucose. Lactose, sucrose, maltose and starch not fermented.

Coagulated albumin liquefied.

Blood serum liquefied.

Brain medium blackened and slowly digested.

Minced pork medium: Slight disintegration; sour, putrefactive odor.

Non-pathogenic.

Optimum temperature 20°C to 25°C. Slow growth at 0°C and no visible growth at 37°C.

Anaerobic.

Source: From muscle tissue of hogs at slaughter.

Habitat: Not determined, other than this source.

47. **Clostridium nigrificans** Werkman and Weaver. (Iowa State Coll. Jour. Sci., *2*, 1927–28, 63; Werkman, Iowa State Coll. Research Bull. 117, 1929, 165.) From Latin *niger*, black and *faciens*, making.

Rods: 0.3 to 0.5 by 3.0 to 6.0 microns, with rounded ends. Motile. Spores oval, subterminal, slightly swelling rods. Gram-positive.

Gelatin: Not liquefied.

Deep agar colonies: Show blackening of medium around colonies. Black increased by adding 0.1 per cent ferric chloride to medium.

Milk: Not recorded.

Indole not formed.

Nitrites not produced from nitrates.

Glucose not fermented.

Carbohydrates not fermented.

Coagulated albumin not liquefied.

Blood serum not liquefied.

Brain medium blackened but not digested.

Hydrogen sulfide produced from cystine.

Non-pathogenic to man, guinea pig, mouse, rat and rabbit.

Optimum temperature 55°C. Thermophilic, growing at 65°C to 70°C.

Anaerobic.

Distinctive character: Black colonies in agar media.

Source: From canned corn showing sulfur stinker spoilage; also occasionally from soil and manure.

Habitat: Presumably soil, although detected with great difficulty.

48. **Clostridium belfantii** (Carbone and Venturelli) Spray. (*Bacillus belfantii* Carbone and Venturelli, Boll. Ist. Sieroter., Milan, 4, 1925, 59; not *Bacillus belfantii* Migula, Syst. d. Bakt., 2, 1900, 767; Spray, in Manual, 5th ed., 1939, 759; *Endosporus belfantii* Prévot, Ann. Inst. Past., *61*, 1938, 75.) Named for Belfanti, an Italian bacteriologist.

Rods: 0.4 to 0.6 by 1.5 to 7.0 microns, thick and straight, occurring singly, in pairs and in short chains. Motile. Spores large, oval, central to subterminal, swelling rods. Usually Gram-negative, occasional cells Gram-positive.

Granulose reaction negative

Gelatin: Not liquefied.

Plain agar surface colonies (anaerobic): Large, round, opaque, with filamentous edge.

Deep agar colonies: Arborescent along the stab. Gas is formed.

Plain broth: Diffuse turbidity, clearing by precipitation. No pigmentation. Gas is formed.

Potato mash: Forms a foam becoming violet in 24 to 48 hours, persisting 3 to 6 days, but disappearing on exposure to air.

Potato slant: Grayish pellicle, becoming violet in 24 to 48 hours. Gas of alcoholic odor is produced. No acetone.

Glycerinated potato: Thin, grayish pellicle, not becoming violet.

Milk: Coagulated in 24 to 48 hours. Clot broken by gas.

Milk agar: Abundant growth. Gas of butyric odor is liberated.

Indole is formed.

Hydrogen sulfide not formed.

Acid and gas from glucose, fructose, maltose, sucrose, lactose and mannitol. Starch and inulin weakly fermented.

Coagulated albumin not liquefied.

Blood serum not liquefied.

Grows well at 37°C.

Anaerobic.

Specifically agglutinated only by homologous antiserum.

Source: From retting beds and from air.

Habitat: Not determined, other than these sources.

Note: Six other strains of similar pigmenting, sporulating anaerobes are described by the authors. These have the general characters of *Clostridium belfantii*, but differ in certain particulars, such as color of pigment, fermentation and specific agglutination. Present information does not permit accurate systematic differentiation.

48a. *Clostridium maggiorai* (Carbone and Venturelli) Spray. (*Bacillus maggiorai* Carbone and Venturelli, *loc. cit.*, 59; Spray, in Manual, 5th ed., 1939, 759; *Endosporus maggiorai* Prévot, *loc. cit.*, 76.) Named for Maggiora, an Italian bacteriologist.

Characters in general those of the group, but does not produce indole.

Violet pigmentation persisting only 24 hours.

No alcoholic odor from cultures.

Specifically agglutinated only by homologous antiserum.

From mud from bed of stream in Italy.

48b. *Clostridium derossii* (Carbone and Venturelli) Spray. (*Bacillus de rossii* Carbone and Venturelli, *loc. cit.*, 59; Spray, in Manual, 5th ed., 1939, 760; *Endosporus rossii* Prévot, *loc. cit.*, 76.) Named for G. de Rossi, an Italian bacteriologist.

Characters in general those of the group. Greenish pigmentation on potato slant, changing to violet or orange.

Indole is formed.

Spedifically agglutinated only by homologous antiserum.

From soil in Italy.

48c. *Clostridium ottolenghii* (Carbone and Venturelli) Spray. (*Bacillus ottolenghii* Carbone and Venturelli, *loc. cit.*, 59; Spray, in Manual, 5th ed., 1939, 760;

Endosporus ottolenghii Prévot, *loc. cit.*, 76.) Named for Ottolenghi, an Italian bacteriologist.

Characters in general those of the group. Potato slant digested to a grayish-brown mash. Greenish pigment changing to reddish. Gas of disagreeable odor is formed.

Indole is formed.

Specifically agglutinated only by homologous antiserum.

From mud from bed of a stream in Italy.

48d. *Clostridium paglianii* (Carbone and Venturelli) Spray. (*Bacillus paglianii* Carbone and Venturelli, *loc. cit.*, 60; not *Bacillus paglianii* Trevisan, I generi e le specie delle Batteriacee, 1889, 19; Spray, in Manual, 5th ed., 1939, 760; *Endosporus paglianii* Prévot, *loc. cit.*, 76.) Named for Pagliani, an Italian bacteriologist.

Characters in general those of the group. One or two subterminal spores are said to be formed.

Greenish pigmentation on potato, browning with age.

Indole is formed.

Specifically agglutinated only by homologous antiserum.

From soil in Italy.

48e. *Clostridium lustigii* (Carbone and Venturelli) Spray. (*Bacillus lustigii* Carbone and Venturelli, *loc. cit.*, 59; not *Bacillus lustigii* Trevisan, *in litt.*, quoted from DeToni and Trevisan, in Saccardo, Sylloge Fungorum, *8*, 1889, 958; not *Bacillus lustigi* Chester, Man. Determ. Bact., 1901, 304; Spray, in Manual, 5th ed., 1939, 760; *Endosporus lustigii* Prévot, *loc. cit.*, 76.) Named for Lustig, an Italian bacteriologist.

Characters in general those of the group. Green pigmentation on potato slant.

Indole is not formed.

Specifically agglutinated only by homologous antiserum.

From mud and soil in Italy.

48f. *Clostridium sclavoi* (Carbone and Venturelli) *comb. nov.* (*Bacillus sclavoi* Carbone and Venturelli, *loc. cit.*, 60; *Endosporus sclavoei* Prévot, *loc. cit.*, 76.) Named for Sclavo, an Italian bacteriologist.

Characters in general those of the group. Greenish to brown pigmentation on potato slant.

Indole is not formed.

Specifically agglutinated only by homologous antiserum.

From retting flax in Italy.

49. **Clostridium venturelli** (de Tomasi) Spray. (*Bacillus venturelli* de Tomasi, Boll. Ist. Sieroter. Milanese, *4*, 1925, 203; *Endosporus venturelli* Prévot, Ann. Inst. Past., *61*, 1938, 76; Spray, in Manual, 5th ed., 1939, 769.) Named for Venturelli, an Italian bacteriologist.

Rods: Pleomorphic, fusiform to straight or slightly curved, with rounded ends. Size variable with medium, 0.5 to 0.8 by 2.5 to 8.0, and up to 20.0 microns. Occurring singly, in pairs, in chains, or frequently in parallel groupings. Motile. Capsulated. Spores oval, central to excentric, swelling rods. Gram-negative.

Granulose reaction positive; showing violet granules with iodine.

Gelatin: No growth; no liquefaction.

Glucose agar surface colonies (anaerobic): Round, becoming rose-colored.

Plain agar slant (anaerobic): No growth.

Maltose agar stab: Colonies lenticular, yellowish, turning to rose. Odor of acetone.

Plain broth: No growth.

Potato slant (anaerobic): Becomes mucilaginous. Bubbles of gas of amylic odor.

Potato mash: Very abundant growth; rose color, with red spots.

Milk with $CaCO_3$: Coagulated; becoming yellow, then pale rose. Amylic odor.

Acid and gas from glucose, maltose, sucrose, fructose, lactose, inositol, dextrin and starch. Arabinose, glycerol, mannitol and inulin not fermented (cited from Weinberg et al., Les Mic. Anaér., 1937, 800).

Fermentation products include especially acetone and amyl alcohol, and smaller amounts of propyl, butyl and isobutyl alcohols, and acetic acid.

Coagulated albumin not digested.

Blood serum not liquefied; forms a small amount of yellowish liquid.

Optimum temperature 18°C to 20°C. Inhibition of growth and pigmentation above 25°C.

Anaerobic.

Distinctive character: Forms a rose-colored pigment which is soluble in alcohol, but not in water, ether or chloroform.

Source: From potato.

Habitat: Not determined, other than this source.

50. **Clostridium roseum** McCoy and McClung. (Arch. f. Mikrobiol., *6*, 1935, 237.) From Latin *roseum*, pink.

Rods: 0.7 to 0.9 by 3.2 to 4.3 microns, occurring singly, in pairs and in short chains. Motile with peritrichous flagella. Spores oval, subterminal, swelling rods to clostridia. Gram-positive, becoming Gram-negative.

Granulose reaction positive in clostridial stage.

Glucose gelatin: Liquefied.

Plain agar slant (anaerobic): Surface growth scant, scarcely perceptible.

Glucose agar surface colonies (anaerobic): Raised, smooth, edges slightly irregular. Pink to orange pigment.

Deep glucose agar colonies: Compact, lenticular, pink to red-orange.

Blood agar not hemolyzed.

Pigmentation (anaerobic): Colonies red-orange, becoming purplish-black on aeration.

Plain broth: No growth.

Glucose broth: Abundant, uniform turbidity, with much gas.

Litmus milk: Stormy coagulation. Litmus reduced, but obscured by pink pigment. Clot slowly softened. Proteolysis demonstrable on milk agar.

Potato: Rapid digestion to a clear yellow fluid and bluish sediment. Much gas with butylic odor.

Corn mash: Resembling reaction of *Clostridium acetobutylicum*, but with flesh-orange pigment, becoming slowly purple at surface on ageing.

Hydrogen sulfide formed from thiosulfate and sulfite.

Nitrates reduced to ammonia.

Nitrites reduced to ammonia.

Indole not formed.

Acid and gas from xylose, arabinose, glucose, mannose, fructose, galactose, lactose, maltose, sucrose, raffinose, starch, dextrin, glycogen, inulin, pectin and salicin. Esculin and amygdalin weakly fermented. Mannitol, erythritol, glycerol, α-methyl glucoside, Ca-lactate and cellulose not fermented.

Coagulated albumin cubes: Softened and yellowed by slow digestion.

Blood serum not liquefied.

Brain medium not blackened or digested.

Non-pathogenic for guinea pig and rabbit.

Optimum temperature about 37°C. Growth occurs from 8°C to 62°C.

Anaerobic.

Source: From German maize.

Habitat: Probably occurs in soil.

51. **Clostridium chromogenes** Prévot. (Chromogenic anaerobe, Ghon and Mucha, Cent. f. Bakt., I Abt., Orig., *42*, 1906, 406; *Bacillus anaerobius chromogenes* LeBlaye and Guggenheim, Man. Prat. d. Diag. Bact., 1914, 321; Prévot, Ann. Inst. Past., *61*, 1938, 85.) From Latin, color-producing.

Rods: Moderate size, coccoid to elongate, ends rounded to slightly pointed; straight to slightly curved. Occurring singly, paired, in short chains and in long, curved to coiled filaments. Capsulate, especially in serum media. Motile, with many peritrichous flagella. Spores abundant, oval, central, subterminal, to apparently terminal at maturation, swelling rods to clubs and clostridia. Gram-positive.

Granulose negative with iodine solution.

Gelatin: Liquefied in 48 hours. Diffuse turbidity, clearing with abundant, whitish-gray sediment, which later becomes red to violet-red. Upper (1 cm) layer shows diffuse, red pigment.

Deep plain agar (without peptone): Growth sparse. Pigment not formed in absence of peptone.

Blood agar surface colonies (anaerobic): Grayish, moist, shining, flat; edges lobate with finely dendritic-tufted edges. Blood agar is hemolyzed.

Glucose agar surface colonies (anaerobic): As on blood agar. Growth slightly less profuse.

Glucose agar deep colonies: Grayish-white, multi-lobate, with dense center and dendritic, tufted edges. Growth begins about 1 cm below surface. Gas abundantly formed. Diffuse, red pigment appears in superficial layers after 4 to 5 days.

Glucose meat-infusion broth: Abundant, diffuse turbidity with much gas. Gradual, profuse sedimentation, but with prolonged turbidity.

Peptone water: Growth variable; sometimes fails. At best, moderate turbidity and sediment. No gas.

Synthetic fluid media (Uschinsky, etc.): No growth (unless peptone is added). Growth is proportionate to added peptone.

Potato slant (anaerobic): Growth delicate, shining, grayish-yellow. Fecal odor.

Milk: Spongy coagulation after 3 to 4 days. Abundant gas. Turbid, yellowish whey is expressed. Casein clot gradually digested in 4 to 5 weeks. Fecal odor.

Indole is not formed.

Hydrogen sulfide is abundantly formed.

Coagulated albumin (hydrocoel- and ascitic-fluid): Digested and blackened, with moderate gas of fecal odor. When covered with agar, the agar plug shows diffuse, red pigmentation.

Pathogenicity: Weakly pathogenic for white mice and guinea pigs. Produces hemorrhagic, serous peritonitis after intraperitoneal inoculation. Death due apparently to a weak toxin. Virulence increased by animal passage.

Grows well at 21°C and at 37°C.

Anaerobic.

Distinctive character: Red pigmentation which is increased on addition of chlorine-, or of bromine-water. Although produced by an anaerobe, pigment appears only in aerated zone and depends on peptone content of medium.

Source: From pus of a human perinephritic abscess.

Habitat: Not determined, other than this single source.

52. **Clostridium felsineum** (Carbone and Tombolato) Bergey et al. (*Bacillus felsineus* Carbone and Tombolato, Le Staz. Sper. Agrar., Ital., *50*, 1917, 563; Ruschmann and Bavendamm, Cent. f. Bakt., II Abt., *64*, 1925, 340; Van der Lek, Thesis, Delft, 1930, (143?); *Clostridium felsinus* Bergey et al., Manual, 3rd ed., 1930, 453.) Named for Felsinea, the ancient name of Bologna, Italy.

Described from Ruschmann and Bavendamm (*loc. cit.*), from the Kluyver strain used by Van der Lek (*loc. cit.*), and from McCoy and McClung, Arch. f. Mikrobiol., *6*, 1935, 230.

Rods: 0.3 to 0.4 by 3.0 to 5.0 microns, occurring singly, in pairs and in short chains. Motile with peritrichous flagella. Spores oval, subterminal, swelling rods to clostridia. Gram-positive, becoming Gram-negative.

Granulose positive in the clostridial stage.

Glucose gelatin: Liquefied.

Plain agar slant (anaerobic): Surface growth scant, scarcely perceptible.

Glucose agar surface colonies (anaerobic): Raised, smooth, slightly irregular, yellow-orange.

Deep glucose agar colonies: Compact, lenticular, opaque, yellow.

Blood agar not hemolyzed.

Pigmentation (anaerobic): Yellow-orange, ageing to brownish. Not changing on aeration.

Plain broth: No growth.

Glucose broth: Abundant, uniform turbidity, with much gas. Yellow slimy sediment.

Litmus milk: Acid and coagulation. Litmus reduced. Clot torn and yellowed. No visible digestion.

Potato: Digested to a yellow slime. Much gas with butylic odor.

Corn mash: Resembling reaction of *Clostridium acetobutylicum*, but with flesh to orange pigment.

Indole not formed.

Nitrates reduced to ammonia.

Nitrites reduced to ammonia.

Acid and gas from arabinose, xylose, glucose, mannose, fructose, galactose, lactose, maltose, sucrose, raffinose, starch, dextrin, inulin, glycogen, pectin and salicin. Mannitol, erythritol, glycerol, Ca-lactate and cellulose not fermented.

Fermentation products include butyl and ethyl alcohol, acetone, organic acids (probably butyric and acetic), H_2 and CO_2.

Coagulated albumin cubes: Softened and yellowed by slow digestion.

Blood serum not liquefied.

Brain medium not blackened or digested.

Non-pathogenic for guinea pig and rabbit.

Grows at 37°C.

Anaerobic.

Source: From retting flax.

Habitat: Not determined. Found in soil in Italy, Argentina and in the United States.

53. **Clostridium carbonei** Arnaudi. (Soc. Intern. Microbiol., Boll. Sez. Ital., *8*, 1936, 251, and Boll. Ist. Sieroter, Milano, *16*, 1937, 650; *Inflabilis carbonei* Prévot, Man. d. Class., etc., 1940, 96.) Named for Carbone, an Italian bacteriologist.

Rods: 0.8 to 1.0 by 3.5 to 4.5 microns, with ends slightly tapered. Non-motile. Spores oval, terminal, 0.8 to 1.0 by 1.0 to 1.75 microns, swelling rods. Gram-positive.

Granulose reaction strongly positive with iodine solution.

Gelatin: No growth.

Glucose and lactose gelatin: No growth.

Plain agar surface colonies (anaerobic): Flat, shining, colorless, with irregular edges.

Malt agar surface colonies (anaerobic): Creamy to slightly reddish colonies with irregular edges.

Roux-potato slant (anaerobic): Punctiform, raised, opaque, deep red colonies, becoming almost violet.

Plain agar stab: Only traces of growth along stab.

Glucose and maltose agar stab: No growth.

Plain broth: Very slight, colorless, diffuse turbidity.

Glucose broth: Very slight turbidity.

Maltose broth: Intense turbidity, with profuse, reddish-yellow sediment.

Tarozzi broth: Slight, diffuse turbidity.

Indole not formed.

Hydrogen sulfide not formed.

Milk: Soft coagulation, with slight, fine reddish flocculence. Whey turbid and colorless. Reaction acid. Clot not digested.

Digest-milk (optimum medium): Very abundant turbidity, with bright red flocculent sediment, diffusing uniformly on shaking.

Coagulated egg-yolk broth: Slight turbidity; no digestion.

Coagulated egg-albumin broth: Slight turbidity; no digestion.

Coagulated serum (Loeffler, anaerobic): Poor growth; flat, red surface colonies. No digestion.

Brain medium: Not recorded.

Cellulose not attacked. Hemp is not retted.

Ferments weakly: Glucose, maltose, sucrose, galactose, fructose and raffinose. Slow and partial fermentation of lactose (only in acidified medium). Starch slightly fermented. Fermentation products include H_2, CO_2, CH_4, butyric acid and traces of ethyl alcohol.

Non-pathogenic for sheep, rabbit, guinea pig or white mouse.

Optimum reaction pH 7.0 to 7.2; minimum pH 6.0; maximum pH 8.0.

Optimum temperature 37°C. Grows slowly at 25°C to 30°C; growth ceases at 40°C.

Anaerobic.

Distinctive character: Production of a brilliant red pigment, soluble in amyl alcohol, petrol-ether, xylol and aniline oil. Partly soluble in ether, chloroform and acetone. Pigment very stable in light.

Source: From macerated raw potato infusion.

Habitat: Not recorded, other than from this single source.

54. **Clostridium spumarum** (Prévot and Pochon) *comb. nov.* (*Plectridium spumarum* Prévot and Pochon, Compt. rend. Soc. Biol., Paris, *130*, 1939, 966.) From Latin, foam or froth.

Rods: 0.5 by 4.0 microns, motile. Spores are oval and terminal, swelling rods. Gram-positive.

Gelatin: Liquefied in 15 days.

Deep agar: Forms small cottony colonies and a few gas bubbles.

Peptone water: Turbidity and slight sediment.

Milk: Coagulated in 5 days, but clot is not digested.

Indole is produced.

Hydrogen sulfide is formed (medium not stated).

Sugars not attacked immediately after isolation.

After 1 month cultivation, ferments slowly glucose, fructose, galactose, maltose, arabinose, xylose, sucrose, mannitol and starch. Inulin is not fermented.

Cellulose (in synthetic medium) is fermented chiefly to acetic and butyric acids, together with inflammable gas and traces of ethyl alcohol.

Coagulated albumin not attacked.

Brain medium not blackened.

Optimum temperature around 37°C. Not thermopbilic.

Anaerobic.

Distinctive characters: Does not produce pigment, and ferments a variety of carbohydrates.

Source: From the scum of sugar refining vats.

Habitat: Not determined, other than from this source.

55. **Clostridium werneri** Bergey et al. (*Bacillus cellulosam fermentans* Werner, Cent. f. Bakt., II Abt., *67*, 1926, 297; Bergey et al., Manual, 3rd ed., 1930, 452; *Bacterium cellulosam* Jepson, Bull. Entomol. Res., *28*, 1937, 163; *Terminosporus cellulosam fermentans* Prévot, Ann. Inst. Past., *61*, 1938, 86; *Terminosporus cellulosam-fermentans* Prévot, Man. d. Class., etc., 1940, 148.) Named for Erich Werner, the German bacteriologist who first isolated this organism.

Related species: Probably closely related to *Clostridium omelianskii*.

Rods: 0.5 to 0.7 by 1.5 to 7.0 microns, occurring singly and in pairs, but not in chains. Motile with peritrichous flagella. Spores oval, terminal, swelling rods. Gram-negative.

Cellulose agar slant (anaerobic): Growth only in contact with cellulose. Growth grayish-black; agar is darkened. Gas is formed.

Agar slant (anaerobic): No growth.

Broth: No growth.

Broth with filter paper: Poor growth; cellulose weakly attacked.

Omelianski solution with filter paper: Abundant growth; cellulose digested with formation of H_2 and CO_2.

Hydrogen sulfide is formed in the Omelianski medium, presumably from the $(NH_4)_2SO_4$ and $MgSO_4$.

Glucose not fermented.

Carbohydrates, other than cellulose, not fermented.

Non-pathogenic for mice.

Optimum temperature 33°C to 37°C.

Anaerobic.

Source: From larvae of rose leaf beetle (*Potosia cuprea*).

Habitat: Occurs in soil and in feces of herbivorus animals.

56. **Clostridium cellulosolvens** Cowles and Rettger. (Jour. Bact., *21*, 1931, 167; *Caduceus cellulosolvens* Prévot, Ann. Inst. Past., *61*, 1938, 86.) From chemical term, cellulose, and Latin, dissolving.

Rods: 0.5 by 2.0 to 6.0 microns, commonly curving, occurring singly and in pairs, not in chains. Non-motile. Spores spherical, terminal, swelling rods. Gram stain uncertain; usually Gram-negative.

Does not grow in routine media, except where cellulose or certain few carbohydrates are added.

Surface colonies on dextrin-cysteine meat infusion agar (anaerobic): Tiny, round, transparent dew-drops; finely granular, with smooth edge.

Acid and gas from cellulose, dextrin, arabinose, xylose and soluble starch. Glucose, fructose, mannose, lactose, maltose, sucrose, melezitose, raffinose, inulin, salicin, amygdalin, adonitol, dulcitol, erythritol, glycerol, inositol, mannitol, sorbitol and gum arabic not fermented.

Cellulose decomposed to H_2, CO_2 and organic acids.

Grows at 37°C.

Anaerobic.

Source: From horse feces.

Habitat: Not determined, other than this source. Probably widely dispersed in manured soil.

57. **Clostridium dissolvens** Bergey et al. (*Bacillus cellulosae dissolvens* Khouvine, Ann. Inst. Past., *37*, 1923, 711; Bergey et al., Manual, 2nd ed., 1925, 344; *Caduceus cellulosae dissolvens* Prévot, Ann. Inst. Past., *61*, 1938, 86.) From Latin, dissolving.

Rods: Slender, ranging from 2.5 to 12.5 microns in length, occurring singly, occasionally in pairs, but not in chains. Non-motile. Spores oval, terminal, swelling rods. Gram-negative.

Cellulose is digested by the formation of an endocellulase which acts only when the bacteria are attached to the cellulose. Saccharides are formed from cellulose, also CO_2, H_2, ethyl alcohol, acetic, lactic and butyric acids.

A yellow pigment is formed in presence of cellulose.

Glucose not fermented.

Carbohydrates, other than cellulose, not fermented.

Non-pathogenic for guinea pig.

Optimum temperature: Grows between 35°C and 51°C, without a definite optimum.

Anaerobic.

Distinctive character: Grows only in media containing cellulose, in the presence of which it produces a yellow pigment.

Source: From human feces.

Habitat: Intestinal canal of man.

58. **Clostridium omelianskii** (Henneberg *emend.* Clausen) *comb. nov.* (Cellulose fermenting microbe, Omelianski, Compt. rend. Acad. Sci., Paris, *121*, 1895, 653 (*Bacillus fermentationis cellulosae* Omelianski, Arch. Sci. Biol. (Russ.), *7*, 1899, 419; *Bacterium cellulosis* Migula, Syst. d. Bakt., *2*, 1900, 513); Bacille hydrogénique, Omelianski, Arch. Sci. Biol. (Russ.), *9*, 1902–03, 263 (Wasserstoffbacillus, Omelianski, Cent. f. Bakt., II Abt., *8*, 1902, 262; *Bacillus fossicularum* Lehmann and Neumann, Bakt. Diag., 4 Aufl., *2*, 1907, 466; *Bacillus hydrogenii* Jungano and Distaso, Les Anaérobies, 1910, 147; *Bacillus omelianskii* Henneberg, Cent. f. Bakt., II Abt., *55*, 1922, 276, *emend.* Clausen, Cent. f. Bakt., II Abt., *84*, 1931, 40 and 54; *Omelianskillus hydrogenicus* Heller, Jour. Bact., *7*, 1922, 5; *Caduceus cellulosae hydrogenicus* Prévot, Ann. Inst. Past., *61*, 1938, 86); Bacille formenique, Omelianski, Arch. Sci. Biol. (Russ.), *9*, 1902–03, 263 (Methanbacillus, Omelianski, Cent. f. Bakt., II Abt., *11*, 1903–04, 370; *Bacillus methanigenes* Lehmann and Neumann, Bakt. Diag., 4 Aufl., *2*, 1907, 466; *Cellobacillus methanigenes* Orla-Jensen, Cent. f. Bakt., II Abt., *22*, 1909, 343; *Bacillus methanii* Jungano and Distaso, Les

Anaérobies, 1910, 146; *Caduceus cellulosae hydrogenicus* var. *cellulosae methanicus* Prévot, Ann. Inst. Past., *61*, 1938, 86; *Caduceus cellulosae methanicus* Prévot, Man. d. Class., etc., 1940, 150).) Named for Omelianski, the Russian bacteriologist who first described this type.

This species was apparently first isolated and studied in pure culture by Clausen (*loc. cit.*). From his studies he concludes that Omelianski's Wasserstoff- and Methanbacillus are but a single species, and that the gaseous fermentation products (H_2, CO_2 and CH_4) were affected by the symbiotic forms always present in Omelianski's cultures.

His evidence is quite convincing, and the organism is presented here from his description.

Rods: Length varying with the medium, 0.5 to 0.7 by 5.0 to 15.0 microns, straight to slightly curved. Occurring chiefly singly, occasionally in pairs, frequently parallel in groups, never in chains or filaments. Young cells motile, but motility disappearing with sporulation. Flagella not demonstrable. Spores spherical, terminal, swelling rods. Spores 1.0 to 1.5 microns in diameter, varying with medium. Gram-positive, becoming Gram-labile on sporulation.

Young vegetative cells colored wine-red with iodine solution.

Gelatin (plus asparagine): Liquefied in 6 to 10 days. Medium remains perfectly clear.

Asparagine agar deep colonies: Grayish-white, delicate, cottony, with fine radial outgrowths.

Asparagine agar surface colonies (anaerobic): Poor growth, delicate, translucent, filmy, scarcely discernible.

Cellulose-liver broth: Solution remains visibly clear and does not darken with age. Occasional large gas bubbles arise.

Indole not formed.

Ammonia not formed.

Nitrates not reduced to nitrites.

Traces of H_2S produced in inorganic solutions.

Milk: Soft coagulation in 24 hours. Amorphous clot shrinks and settles, forming a yellowish-red to orange sediment, with turbid supernatant whey.

Brain medium: Not digested or blackened; no visible evidence of growth.

None of the following carbohydrates attacked: Maltose, mannitol, lactose, glucose, sucrose, galactose, fructose, starch, salicin, glycerol and inulin.

Cellulose apparently the primary C-source, but is only weakly attacked by pure cultures.

Yellow pigment not recorded in presence of cellulose (see *Clostridium dissolvens*).

Non-pathogenic for mice; other animals not recorded.

Optimum reaction pH 7.0 to 7.4; grows between pH 6.0 and 8.4.

Optimum temperature 37°C to 42°C.

Anaerobic: Growing at 25 to 30 mm mercury pressure.

Distinctive characters: Ability to liquefy gelatin (plus asparagine); to coagulate milk with orange sediment, and to grow in media containing asparagine without requiring presence of cellulose. Spores resist heating at 100°C for 90 minutes.

Source: From human, cow and horse excreta, from cow's stomach contents, from cheese and from soil.

Habitat: Intestinal canal of animals, and presumably thence widely disseminated in soil.

59. **Clostridium carnis** (Klein) Spray. (Art V, von Hibler, Cent. f. Bakt., I Abt., *25*, 1899, 515; *Bacillus carnis* Klein, Cent. f. Bakt., I Abt., Orig., *35*, 1904, 459, also Trans. Path. Soc., London, *55*, 1904, 74; Art. VI, von Hibler, Untersuch. ü. d. Path. Anaer., 1908, 3 and 406; *Hiblerillus sextus* Heller, Jour. Bact., *7*, 1922, 6; *Bacillus lactiparcus* Lehmann and Süssmann, in Lehmann and Neumann, Bakt. Diag., 7 Aufl., *2*, 1927, 647; *Plectridium carnis* Prévot, Ann. Inst. Past., *61*, 1938, 87; Spray, in Bergey et al., Manual, 5th ed., 1939, 750; *Clostridium*

sextum Prévot, Man. d. Class., etc., 1940, 136.) From Latin, of flesh.

Description from Hall and Duffett, Jour. Bact., *29*, 1935, 269.

Rods: 0.5 to 0.7 by 1.5 to 4.5 microns, occurring singly, in pairs, rarely in chains of 3 to 4 cells. Motile with peritrichous flagella. Spores oval to elongate, subterminal, slightly swelling rods. Gram-positive.

Gelatin: Not liquefied or blackened.

Agar surface colonies (aerobic): Minute, transparent dew-drops, becoming flat and lobate.

Blood agar surface colonies (aerobic): Similar to plain agar. Slight hemolysis.

Deep agar colonies: Lenticular, becoming nodular to arborescent.

Milk: Abundant gas, but no coagulation or other change.

Indole not formed.

Acid and gas from glucose, galactose, fructose, maltose, lactose, sucrose, amygdalin, salicin and dextrin. Trehalose, raffinose, xylose, arabinose, starch, inulin, mannitol, dulcitol, sorbitol, glycerol and inositol not fermented.

Coagulated albumin not liquefied.

Blood serum not liquefied.

Brain medium not blackened or digested.

Pathogenic for guinea pig, white rat and rabbit. Forms an exotoxin of moderate intensity, producing edema, necrosis and death on sufficient dosage.

Grows well at both 37°C and at room temperature.

Anaerobic and microaerophilic; growing delicately on aerobic agar slants.

Source: Originally isolated from a rabbit inoculated with garden soil (von Hibler); from contaminated beef infusion (Klein).

Habitat: Probably occurs in soil.

60. **Clostridium histolyticum** (Weinberg and Seguin) Bergey et al. (*Bacillus histolyticus* Weinberg and Seguin, Compt. rend. Acad. Sci., Paris, *163*, 1916, 449; *Weinbergillus histolyticus* Heller, Jour. Bact., *7*, 1922, 9; Bergey et al., Manual, 1st ed., 1923, 328.) From Greek, tissue-dissolving.

Rods: 0.5 to 0.7 by 3.0 to 5.0 microns, occurring singly and in pairs. Motile with peritrichous flagella. Spores oval, subterminal, swelling rods. Gram-positive.

Gelatin: Complete liquefaction in 24 hours.

Blood agar surface colonies (aerobic): Minute, round dew-drops. Blood is hemolyzed.

Deep agar colonies: Variable; from lenticular, lobate, to fluffy, according to the agar concentration.

Agar slant (aerobic): Grows aerobically in barely perceptible film, or in tiny, smooth, discrete colonies.

Broth: Turbid, with slight precipitate.

Indole not formed.

Nitrites not produced from nitrates.

Litmus milk: Softly coagulated, then slowly digested. Little gas is formed.

Carbohydrates are not fermented.

Coagulated albumin slowly liquefied.

Blood serum slowly liquefied with darkened, putrid fluid.

Brain medium blackened and digested with putrefactive odor.

Egg-meat medium: Little gas is formed. Meat first reddened, then darkened in 3 days. Digestion apparent in about 24 hours. Nauseous odor. Tyrosin crystals are abundant after about a week.

Pathogenic for small laboratory animals. Produces a cytolytic exotoxin which causes extensive local necrosis and sloughing on injection. Not toxic on feeding.

Grows well at 37°C.

Anaerobic and microaerophilic. Grows feebly on aerobic agar slant.

Source: Originally isolated from war wounds, where it induces active necrosis of tissue.

Habitat: Not determined, other than source stated. Found occasionally in feces and soil. Apparently widely, but sparsely, dispersed in soil.

61. **Clostridium tertium** (Henry) Bergey et al. (*Bacillus tertius* Henry, Jour. Path. and Bact., *21*, 1916, 347; *Henrillus tertius* Heller, Jour. Bact., *7*, 1922, 5; Bergey et al., Manual, 1st ed., 1923, 332; *Plectridium tertium* Prévot, Ann. Inst. Past., *61*, 1938, 87.) From Latin *tertius*, third.

Probable synonyms: *Bacillus gazogenes parvus* Choukévitch, Ann. Inst. Past., *25*, 1911, 271 (*Bacillus gazogenes* Choukévitch, *ibid.*, 268; *Plectridium gazogenes* Prévot, Ann. Inst. Past., *61*, 1938, 87); Bacillus Y, Fleming, Lancet, *2*, 1915, 376; *Bacillus aero-tertius* Bulloch et al., Med. Res. Counc., Spec. Rept. Ser. 39, 1919, 4; *Bacillus spermoide* Ninni, Pathologica, *21*, 1920, 385 (*Clostridium spermoides* Bergey et al., Manual, 1st ed., 1923, 336; *Palmula spermoides* Prévot, Ann. Inst. Past., *61*, 1938, 88; *Acuformis spermoides* Prévot, Man. d. Class., etc., 1940, 164).

Rods: 0.4 to 0.6 by 3.0 to 6.0 microns, occurring singly and in pairs, not in chains. Motile. Spores oval, terminal, swelling rods. Gram-positive.

Gelatin: Not liquefied.

Agar surface colonies (aerobic): Circular with opalescent, crenated margin.

Deep agar colonies: Small, lenticular, regular, smooth.

Agar slant (aerobic): Grayish, filmy, opalescent growth.

Blood agar is hemolyzed.

Broth: Turbid, with sediment.

Litmus milk: Acid, coagulated, with some gas formation. Clot is not digested.

Indole not formed.

Nitrites produced from nitrates.

Acid and gas from glucose, fructose, galactose, mannose, lactose, maltose, sucrose, arabinose, xylose, trehalose, melezitose, soluble starch, esculin, mannitol, inositol and salicin. Inulin and glycerol not fermented.

Coagulated albumin not liquefied.

Blood serum not liquefied.

Brain medium not blackened or digested.

Meat medium reddened; acid and gas formed. Meat not blackened or digested. Non-putrefactive.

Non-pathogenic for guinea pig and rabbit.

Optimum temperature 30°C to 35°C. Can grow at 50°C.

Anaerobic and microaerophilic. Grows feebly on aerobic agar slant.

Source: From gangrenous wounds and from feces.

Habitat: Widely distributed in soil, feces and sewage.

Appendix I: The following species of anaerobes are listed, chiefly for their historic interest, from descriptions too incomplete to permit present definite classification. Many of these original cultures are now lost, and the descriptions are often too brief even to permit comparison with recognized species. Several were described from cultures of doubtful purity, and even the anaerobic status of some is open to question. The synonymy cited is not to be regarded as definitely established in all instances.

Many strains have been described by number or by common names only. These are not included here, but many may be found listed in Les Microbes Anaérobies, Weinberg, Nativelle and Prévot, Paris, 1937, and in The Anaerobic Bacteria and their Activities in Nature and Disease, McCoy and McClung, Univ. Calif. Press, 1939.

Species are listed alphabetically under the first valid binomial, regardless of their original designation.

Acuformis caninus Prévot. (Unnamed species of Wolbach and Saiki, Jour. Med. Res., *21*, 1909, 267; *Palmula canina* Prévot, Ann. Inst. Past., *61*, 1938, 88; Prévot, Man. d. Class., etc., 1940, 164.) From liver of healthy dog.

Acuformis dubitatus Prévot. (Species No. 1 of Rodella, Cent. f. Bakt., II Abt., *17*, 1907, 374; *Palmula dubitata* Prévot, Ann. Inst. Past., *61*, 1938, 89; Prévot, Man. d. Class., etc., 1940, 165.) From normal and from spoiled milk.

Acuformis immobilis Prévot. (*Bacillus putrificus immobilis* Distaso, Ann. Inst. Past., *23*, 1909, 955; *Palmula immobilis* Prévot, Ann. Inst. Past., *61*, 1938, 89; Prévot, Man. d. Class., etc., 1940, 165.) From intestine of the flying fox (*Pteropus*).

Amylobacter butylicus Duclaux. (Ann. Inst. Past., *9*, 1895, 813.) From fermenting macerated potato inoculated with soil.

Amylobacter ethylicus Duclaux. (Ann. Inst. Past., *9*, 1895, 814.) Probably only a facultative anaerobe. From fermenting macerated potato inoculated with soil.

Bacillus acidi acetici Thöni. (Thesis, Bern, 1906, (?); quoted from McCoy and McClung, The Anaer. Bact. etc., *2*, 1939, 413.) Source not known.

Bacillus aerogenes gangrenosae Weinberg and Ginsbourg. (Bacillo aerogene gangrenosa, Nacciarone, Riforma Med., *33*, 1917, 778; Weinberg and Ginsbourg, Bull. Inst. Past., *23*, 1925, 825.) From human gaseous gangrene.

Bacillus amyloclasticus Renshaw and Fairbrother. (*Bacillus amyloclasticus intestinalis* Renshaw and Fairbrother, Brit. Med. Jour., *1*, 1922, 675; *ibid.*, 818.) Stated by authors to be a facultative anaerobe. From intestine of diabetic persons.

Bacillus anaerobic No. VIII Chester. (Anaerobe No. VIII, Sanfelice, Ztschr. f. Hyg., *14*, 1893, 375; Pseudo-Rauschbrand-bacillus, Kruse, in Flügge, Die Mikroorg., 3 Aufl., *2*, 1896, 250; Chester, Man. Det. Bact., 1901, 296.) From putrefying meat infusions, soil, and from tissues of guinea pigs after inoculation with soil.

Bacillus butyricus Botkin. (Botkin, Ztschr. f. Hyg., *11*, 1892, 421; Bacillus No. I, Flügge, Ztschr. f. Hyg., *17*, 1894, 290; *Bacillus botkini* Migula, Syst. d. Bakt., *2*, 1900, 594; *Bacillus parabutyricus* LeBlaye and Guggenheim, Man. Prat. de Diag. Bact., 1914, 324; not *Bacillus parabutyricus* Gratz and Vas, Cent. f. Bakt., II Abt., *41*, 1914, 510; *Clostridium butyricum* Holland, Jour. Bact., *5*, 1920, 217 and 222.) From milk.

Bacillus butyricus dimorphus Rocchi. (Cent. f. Bakt., I Abt., Orig., *60*, 1911, 580.) A collective name for a group of butyric anaerobes considered denaturable and mutually interconvertible.

Bacillus cadaveris grandis Sternberg. (Researches relating to the etiology and prevention of yellow fever, Washington, 1891, 213.) From liver of a yellow fever cadaver.

Bacillus cannabinus Makrinow and Tchijowa. (Arch. Sci. Biol. (Russ.), *29*, 1929, 52; also Cent. f. Bakt., II Abt., *80*, 1930, 59.) Stated by the authors to be a facultative anaerobe. From soil and from retting of kenaf (*Hibiscus cannabinus*).

Bacillus cincinnatus Gerstner. (Gerstner, Thesis, Basel, 1894, 17; *Bacillus cincinnati* Jungano and Distaso, Les Anaérobies, 1910, 88.) From soil and sewage.

Bacillus clavatus Migula. (Anaerobe No. III, Flügge, Ztschr. f. Hyg., *17*, 1894, 289; Migula, Syst. d. Bakt., *2*, 1900, 597; *Bacillus cuneatus* Chester, Man. Determ. Bact., 1901, 299.) From boiled cow's milk.

Bacillus colicogenes Tissier. (Ann. Inst. Past., *26*, 1912, 523.) From stool of an infant with diarrhea and colic.

Bacillus coprogenes Hopffe. (*Bacillus coprogenes foetidus* Herfeldt, Cent. f. Bakt., II Abt., *1*, 1895, 77; not *Bacillus coprogenes foetidus* Flügge, Die Mikroorg., 2 Aufl., 1886, 305; Hopffe, Ztschr. Infkrnkh. u. Hyg. Haust., *14*, 1913, 404.) From manure and from horse intestine.

Bacillus cresologenes Rhein. (Rhein, Compt. rend. Soc. Biol., Paris, *87*, 1922, 576; *Clostridium cresologenes* Prévot, Ann. Inst. Past., *61*, 1938, 85.) From brain medium inoculated with soil.

Bacillus de baryanus Klein. (Ber. d. Deuts. Bot. Gesellsch., 7 (Bhft.), 1889, 60.) Migula (Syst. d. Bakt., *2*, 1900, 640) says this is probably anaerobic. Observed in swamp water, but not cultivated on artificial media.

Bacillus diffrangens Gerstner. (Thesis, Basel, 1894, 19.) From soil and sewage.

Bacillus dimorphobutyricus Lehmann and Neumann. (Dimorpher Buttersäurebacillus, Grassberger and Schattenfroh, Arch. f. Hyg., *60*, 1907, 59; Lehmann and Neumann, Bakt. Diag., 4 Aufl., *2*, 1907, 441.) From milk.

Bacillus elegans Romanovitch. (Compt. rend. Soc. Biol., Paris, *71*, 1911, 169.) From normal human intestine and from diseased appendix.

Bacillus fibrosus Gerstner. (Thesis, Basel, 1894, 26.) From soil and sewage.

Bacillus flüggei Migula. (Anaerobe No. IV, Flügge, Ztschr. f. Hyg., *17*, 1894, 290; Migula, Syst. d. Bakt., *2*, 1900, 597.) From boiled cow's milk.

Bacillus fossicularum Lehmann and Neumann. (Wasserstoffbacillus, Omelianski, Cent. f. Bakt., II Abt., *8*, 1902, 262; Lehmann and Neumann, Bakt. Diag., 4 Aufl., *2*, 1907, 466, may have been named in the 3 Aufl.) From mud from canals. Forms hydrogen and CO_2 from anaerobic cellulose fermentations.

Bacillus funicularis Gerstner. (Thesis, Basel, 1894, 24.) From soil and sewage.

Bacillus gangraenae Tilanus. (Nederl. Tijdschr. v. Geneeskunde, *21*, 1885, 110.) From a gangrenous human leg.

Bacillus gracilis ethylicus Achalme and Rosenthal. (Compt. rend. Soc. Biol., Paris, *58*, 1906. 1025.) From stomach contents in a case of gastritis.

Bacillus granulosus Gerstner. (Gerstner, Thesis, Basel, 1894, 21; *Bacillus granulatus* Migula, Syst. d. Bakt., *2*, 1900, 613.) From soil and sewage.

Bacillus haumani Soriano. (Unnamed plectridium, Sordelli and Soriano, Compt. rend. Soc. Biol., Paris, *99*, 1928, 1517; Plectridio amarillo, Soriano, Tomo commemorativo del XXV aniversario de la fundación de la Facultad de Agronomia y Veterinaria, Buenos Aires, 1929, (?); Soriano, Rev. Inst. Bact., Buenos Aires, *5*, 1930, 743; *Plectridium amarillum* Stampa, Ann. Brass. et Distill., *29*, 1930–31, (253, 271 and 302?); *Bacillus haumanni* Arnaudi, Boll. Ist. Sieroter., Milano, *16*, 1937, 650; *Clostridium haumanni* Prévot, Ann. Inst. Past., *61*, 1938, 81.) From flax-retting beds.

Bacillus ichthyismi Konstansoff. (Vestnik Obshtch. Hig. Sudeb. i Prakt. Med., Petrograd, *51*, 1915, (766?); quoted from Weinberg et al., Les Microbes Anaérobies, 1937, 341.) From fish responsible for a condition simulating botulism.

Bacillus indolicus Gratz and Vas. (Gratz and Vas, Cent. f. Bakt., II Abt., *41*, 1914, 511; *Inflabilis indolicus* Prévot, Ann. Inst. Past., *61*, 1938, 77.) From cheese.

Bacillus infantilism Hill and Whitcomb. (Amer. Jour. Pub. Health, *3*, 1913, 926.) From human intestine.

Bacillus inflatus Koch. (Koch, Botan. Zeit., *46*, 1888, 328; *Clostridium inflatum* Trevisan, I generi e le specie delle Batteriacee, 1889, 22; not *Bacillus inflatus* Distaso, Ann. Inst. Past., *23*, 1909, 955.) Anaerobic status insecure; aerobic according to Kruse, in Flügge, Die Mikroorg., 3 Aufl., *2*, 1896, 259. Observed in swamp waters, but not isolated. Formed two spores in a spindle-shaped sporangium.

Bacillus irregularis Choukévitch. (Choukévitch, Ann. Inst. Past., *25*, 1911, 348; *Clostridium irregularis* Prévot, Ann. Inst. Past., *61*, 1938, 85.) From large intestine of horse.

Bacillus kedrowskii Migula. (*Bacillus* No. 2, Kedrowski, Ztschr. f. Hyg., *16*, 1894, 451; *Bacillus acidi butyrici* Kruse, in Flügge, Die Mikroorg., 3 Aufl., *2*, 1896, 256; not *Bacillus acidi butyrici I* Weigmann, Cent. f. Bakt., II Abt., *4*, 1898, 830 (see *Bacillus pseudonavicula*); Migula, Syst. d. Bakt., *2*, 1900, 589.) From cheese and rancid butter.

Bacillus lactopropylbutyricus Tissier. (Apparently identical with *Bacillus lactopropylbutyricus non liquefaciens* Tissier and Gasching, Ann. Inst. Past., *17*, 1903, 546; Tissier, Ann. Inst. Past., *19*, 1905, 282; *Clostridium lactopropylbutylicum* Prévot, Ann. Inst. Past., *61*, 1938, 85; *Bacillus lactopropylbutylicus non*

liquefaciens Prévot, Man. d. Class., etc., 1940, 141.) From milk.

Bacillus lichenoides Piening. (Cent. f. Bakt., I Abt., Orig., *124*, 1932, 217; not *Bacillus lichenoides* Grohmann, Cent. f. Bakt., II Abt., *61*, 1924, 267.) Cited only by name, without description. From dried sheep intestines used for preparation of catgut sutures.

Bacillus limosus Klein. (Ber. d. Deutsch. Bot. Gesellsch., *7* (Bhft.), 1889, 60.) Migula (Syst. d. Bakt., *2*, 1900, 640) says this is probably anaerobic. Observed in swamp water, but not cultivated on artificial media.

Bacillus longus Chester. (*Bacillus muscoides colorabilis* Ucke, Cent. f. Bakt., I Abt., *23*, 1898, 1000; Chester, Man. Determ. Bact., 1901, 303.) From garden soil.

Bacillus lubinskii Kruse. (Tetanusähnlicher Bacillus, Lubinski, Cent. f. Bakt., *16*, 1894, 771; Kruse, in Flügge, Die Mikroorg., 3 Aufl., *2*, 1896, 267.) From a fetid human abdominal abscess in peritonitis.

Bacillus lyticus Costa and Troisier. (Compt. rend. Soc. Biol., Paris, *78*, 1915, 433.) From gangrenous war wounds. Stated to be intermediate between *Clostridium perfringens* and *Clostridium septicum*.

Bacillus macrosporus Klein. (Ber. d. Deutsch. Bot. Gesellsch., *7* (Bhft.), 1889, 60.) Migula (Syst. d. Bakt., *2*, 1900, 640) says this is probably anaerobic. Observed in swamp water, but not cultivated on artificial media.

Bacillus makrono-filiformis Becker. (Ztschr. f. Infkrnkh. d. Haust., *23*, 1922, 20.) From a guinea pig cadaver.

Bacillus maymonei Carbone. (Boll. Sez. Ital., Soc. Intern. Microbiol., *1*, 1929, 74.) A retting organism of doubtful purity and anaerobic status. Cultivated from kenaf (*Hibiscus cannabinus*).

Bacillus megalosporus Choukévitch. (Choukévitch, Ann. Inst. Past., *25*, 1911, 351; *Hiberillus megalosporus* Heller, Jour. Bact., *7*, 1922, 17; *Inflabilis megalosporus* Prévot, Ann. Inst. Past., *61*, 1938, 77.) From large intestine of horse.

Bacillus multiformis Distaso. (Distaso, Cent. f. Bakt., I Abt., Orig., *59*, 1911, 101; not *Bacillus multiformis* van Senus, Dissert., Leiden, 1890, (?); *Bacteroides multiformis* Bergey, Manual, 1st ed., 1923, 263; *Cillobacterium multiforme* Prévot, Ann. Inst. Past., *60*, 1938, 297.) Stated by Distaso (*loc. cit.*) not to produce spores, but to belong probably to the Welch Group. From feces of dog.

Bacillus multiformis van Senus. (van Senus, Dissert., Leiden, 1890 and Koch's Jahrsber., *1*, 1890, 138.) From mud and from decomposing vegetation.

Bacillus muscoides Liborius. (Liborius, Ztschr. f. Hyg., *1*, 1886, 163; *Cornilia muscoides* Trevisan, I generi e le specie delle Batteriacee, 1889, 22.) From mouse inoculated with soil, from cheese, and from bovine feces.

Bacillus muscoides non colorabilis Ucke. (Cent. f. Bakt., I Abt., *23*, 1898, 1000.) From hay infusion.

Bacillus nanus Romanovitch. (Compt. rend. Soc. Biol., Paris, *71*, 1911, 239.) From human intestine.

Bacillus nebulosus Vincent. (Ann. Inst. Past., *21*, 1907, 69; not *Bacillus nebulosus* Wright, Mem. Nat. Acad. Sci., 7, 1894, 465; not *Bacillus nebulosus* Hallé, Thèse de Paris, 1898, 33; not *Bacillus nebulosus* Migula, Syst. d. Bakt., *2*, 1900, 844; not *Bacillus nebulosus* Goresline, Jour. Bact., *27*, 1934, 52.) From well and river water.

Bacillus oedematis Migula. (*Bacillus oedematis maligni* Liborius, Ztschr. f. Hyg., *1*, 1886, 158; not *Bacillus oedematis maligni* Zopf, Die Spaltpilze, 3 Aufl., 1885, 88; Migula, Syst. d. Bakt., *2*, 1900, 604; not *Bacillus oedematis* Chester, Man. Determ. Bact., 1901, 292.)

Bacillus otitidis sporogenes putrificus von Hibler. (Cent. f. Bakt., I Abt., Orig., *68*, 1913, 282.) From a human brain abscess.

Bacillus otricolare Weinberg and Ginsbourg. (Bacillo otricolare, Nacciarone, Riforma Med., *33*, 1917, 778; Weinberg

and Ginsbourg, Bull. Inst. Past., *23*, 1925, 825; *Endosporus otricolare* Prévot, Ann. Inst. Past., *61*, 1938, 75.) From human gaseous gangrene.

Bacillus pappulus de Gasperi. (de Gasperi, Cent. f. Bakt., I Abt., Orig., *58*, 1911, 1; *Paraplectrum pappulum* Prévot, Ann. Inst. Past., *61*, 1938, 75.) From rancid sausages.

Bacillus parabutyricus Gratz and Vas. (Gratz and Vas, Cent. f. Bakt., II Abt., *41*, 1914, 510; not *Bacillus parabutyricus* LeBlaye and Guggenheim, Man. Prat. de Diag. Bact., 1914, 324.) From Liptauer cheese.

Bacillus penicillatus Gerstner. (Inaug. Diss., Basel, 1894, 27.) From soil and sewage.

Bacillus peroniella Klein. (Ber. d. Deutsch. Bot. Gesellsch., *7* (Bhft.), 1889, 60.) Migula (Syst. d. Bakt., *2*, 1900, 640) says this is probably anaerobic. Observed in swamp water, but not cultivated on artificial media.

Bacillus polypiformis Liborius. (Liborius, Ztschr. f. Hyg., *1*, 1886, 162; *Cornilia polypiformie* Trevisan, I generi e le specie delle Batteriacee, 1889, 22; Anaerobe No. II, Sanfelice, Ztschr. f. Hyg., *14*, 1893, 369; *Bacillus cephaloideus* Migula, Syst. d. Bakt., *2*, 1900, 631.) From mouse inoculated with soil.

Bacillus postumus Heim. (Heim, Lehrbuch d. Bakt., 3 Aufl., 1906, (?) (p. 259 in 6 Aufl.); quoted from Würcker, Sitzungsber. d. Physik.-Med. Soz. in Erlangen, *41*, 1909, 230; also Heim, Cent. f. Bakt., I Abt., Orig., *55*, 1910, 341.) From various spontaneously putrefying infusions.

Bacillus pseudomagnus Migula. (Anaerobe No. VI, Sanfelice, Ztschr. f. Hyg., *14*, 1893, 373; Migula, Syst. d. Bakt., *2*, 1900, 608; *Bacillus caris* Chester, Man. Determ. Bact., 1901, 293.) From putrefying meat infusions, soil and animal excreta.

Bacillus pseudonavicula Migula. (Species No. 1, Kedrowski, Ztschr. f. Hyg., *16*, 1894, 445; *Bacillus acidi butyrici I* Weigmann, Cent. f. Bakt., II Abt., *4*, 1898, 830; not *Bacillus acidi butyrici* Kruse, in Flügge, Die Mikroorg., 3 Aufl., *2*, 1896, 256; Migula, Syst. d. Bakt., *2*, 1900, 590.) From cheese and rancid butter.

Bacillus pseudooedematis Kruse. (Pseudo - Oedembacillen, Liborius, Ztschr. f. Hyg., *1*, 1886, 163; *Bacillus pseudo-oedematis maligni* Gerstner, Inaug. Diss., Basel, 1894, 35; not *Bacillus pseudooedematis maligni* Sanfelice, Ann. dell'Ist. d'Ig. di Roma, n.s. *1*, 1891, 370; Anaerobe No. VII, Sanfelice, Ztschr. f. Hyg., *14*, 1893, 374; Kruse, in Flügge, Die Mikroorg., 3 Aufl., *2*, 1896, 239; *Bacillus pseudoedematis* Chester, Man. Determ. Bact., 1901, 293; presumably identical with *Bacillus pseudo-septicus* Perrone, Ann. Inst. Past., *19*, 1905, 371, and, according to Perrone, with *Proteus hominis capsulatus* Bordoni-Uffreduzzi, Ztschr. f. Hyg., *3*, 1888, 333.) From mouse inoculated with soil, from putrefying meat infusions and from animal excreta.

Bacillus pseudosolidus Migula. (Anaerobe No. III, Sanfelice, Ztschr. f. Hyg., *14*, 1893, 371; Migula, Syst. d. Bakt., *2*, 1900, 630; *Bacillus tardus* Chester, Man. Determ. Bact., 1901, 294; not *Bacillus tardus* Choukévitch, Ann. Inst. Past., *25*, 1911, 350.) From putrefying meat infusions, soil, and from animal excreta.

Bacillus pseudotetani Migula. (Pseudotetanusbacillus, Tavel and Lanz, Mitt. a. klin. med. Inst. d. Schweiz, *1*, 1893, 162; Migula, Syst. d. Bakt., *2*, 1900, 598; *Bacillus taveli* Chester, Man. Determ. Bact., 1901, 304.) From cases of intestinal abscesses.

Bacillus pseudotetanicus Kruse. (Anaerobe IX, Sanfelice, Ztschr. f. Hyg., *14*, 1893, 375; Kruse, in Flügge, Die Mikroorg., 3 Aufl., *2*, 1896, 267; not *Bacillus pseudotetanicus* Migula, Syst. d. Bakt., *2*, 1900, 626; not *Bacillus pseudotetanicus* Chester, Man. Determ. Bact., 1901, 302; *Bacillus subtetanicus* Migula, *loc. cit.*, 629.) From putrefying meat infusions and from soil.

Bacillus putrificus coagulans Distaso. (Cent. f. Bakt., I Abt., Orig., *59*, 1911, 97.) From human and animal intestine.

Bacillus putrificus var. *non liquefaciens* Putzu. (Policlin., Sez. Chir., *23*, 1916, 225.) From human gas gangrene.

Bacillus putrificans immobilis Distaso. (Ann. Inst. Past., *23*, 1909, 962.) From the feces of the flying fox (*Pteropus*).

Bacillus pyogenes foetidus Herfeldt. (Cent. f. Bakt., II Abt., *1*, 1895, 77.) From manure and from horse intestine.

Bacillus reniformis Gerstner. (Gerstner, Inaug. Diss., Basel, 1894, 22; *Bacterium reniforme* Migula, Syst. d. Bakt., *2*, 1900, 329.) From soil and sewage.

Bacillus rubellus Okada. (Okada, Cent. f. Bakt., *11*, 1892, 4; *Clostridium rubellum* Prévot, Ann. Inst. Past., *61*, 1938, 85.) From dust and dirt.

Bacillus saccharofermentans de Gasperi. (Compt. rend. Soc. Biol., Paris, *67*, 1909, 494.) From putrefying carcasses of game birds.

Bacillus saccharogenes Romanovitch. (Compt. rend. Soc. Biol., Paris, *71*, 1911, 168.) From human intestine, both normal and during appendicitis.

Bacillus saprogenes I, II and *III*, Herfeldt. (Herfeldt, Cent. f. Bakt., II Abt., *1*, 1895, 77; not *Bacillus saprogenes* Salus, Arch. f. Hyg., *51*, 1904, 115.) From manure and from horse intestine.

Bacillus saprogenes intestinalis Romanovitch. (Compt. rend. Soc. Biol., Paris, *71*, 1911, 237.) From human intestine.

Bacillus saprophyticus Maes. (Surg. Clin. North Amer., *10*, 1930, 792.) Only casual mention of this organism as one of the common gas bacilli. Otherwise unidentified.

Bacillus saprotoxicus Sordelli, Soriano, Ferrari and Torino. (Sordelli et al., Rev. d. Inst. Bact., Buenos Aires, *6*, 1934, 432; *Clostridium saprotoxicum* Prévot, Ann. Inst. Past., *61*, 1938, 83.) From human gaseous gangrene.

Bacillus sarcoemphysematodes hominis Conradi and Bieling. (Münch. med. Wchnschr., *63*, 1916, 133.) From human lesions.

Bacillus satellitis Loris-Melikov. (Unnamed species of Loris-Melikov, Compt. rend. Soc. Biol., Paris, *70*, 1911, 865; Loris-Melikov, Ann. Inst. Past., *27*, 1913, 545; *Bacillus satelitis* (sic) Loris-Melikov, Compt. rend. Acad. Sci., Paris, *156*, 1913, 346; *Inflabilis satellitis* Prévot, Ann. Inst. Past., *61*, 1938, 77.) From human typhoid feces.

Bacillus scatologenes Weinberg and Ginsbourg. (Skatol-liberating *Clostridium*, Fellers, Abst. Bact., *7*, 1923, 351; Bacillus skatol, Fellers and Clough, Jour. Bact., *10*, 1925, 105; Weinberg and Ginsbourg, Les Microbes Anaérobies, Paris, 1927, 54.) From spoiled canned macaroni and salmon.

Bacillus septicus Klein. (Klein, Micro-Organisms and Disease, London, 1884, 78; not *Bacillus septicus* Macé, Traité Prat. d. Bact., 1st ed., 1888, 455; not *Bacillus septicus* Migula, Syst. d. Bakt., *2*, 1900, 646.) Probably synonymous with *Clostridium perfringens* Type A. From earth, putrid blood and other albuminous fluids, and occasionally in blood-vessels of man and animals after death.

Bacillus solidus Lüderitz. (Lüderitz, Ztschr. f. Hyg., *5*, 1889, 152; not *Bacillus solidus* Chester, Ann. Rept. Del. Col. Agr. Exp. Sta., *10*, 1898, 129; *Cornilia solida* Trevisan, I generi e le specie delle Batteriacee, 1889, 22.) From mouse and guinea pig inoculated with soil.

Bacillus solmsii Klein. (Klein, Ber. d. Deutsch. Bot. Gesellsch., *7* (Bhft.), 1889, 60; *Diplectridium solmsii* Fischer, Jahrb. f. Wiss. Bot., *27*, 1895, 148). Migula (Syst. d. Bakt., *2*, 1900, 640) says this is probably anaerobic. Observed in swamp water, but not cultivated on artificial media.

Bacillus spinosus Lüderitz. (Lüderitz, Ztschr. f. Hyg., *5*, 1889, 152; *Cornilia spinosa* Trevisan, I generi e le specie delle Batteriacee, 1889, 22.) From mouse and guinea pig inoculated with soil.

Bacillus sporogenes Migula. (*Bacillus enteritidis sporogenes* Klein, Cent. f. Bakt., I Abt., *18*, 1895, 737; Migula, Syst. d. Bakt., *2*, 1900, 560; *Bacillus (enteritidis) sporogenes* and *Bacillus enteritidis* Klein, Loc. Govt. Bd., Ann. Rept. Med. Off., London, *33*, 1903-04, 442 and 443; *Bacillus sporogenes capsulatus* Rettger, Jour. Biol. Chem., *2*, 1906-07, 84; *Bacillus enteritidis-sporogenes* Holland, Jour. Bact., *5*, 1920, 218; *Clostridium enteritidis-sporogenes* Holland, *ibid.*, 218; *Clostridium enteritidis sporogenes* Holland, *ibid.*, 222; *Clostridium sporogenes* Holland, *ibid.*, 220.) Probably a culture of *Clostridium perfringens* contaminated with *Clostridium bifermentans* or with *Clostridium sporogenes*. From epidemic diarrheal feces, and from milk presumably causing the epidemic.

Bacillus sporogenes non liquefaciens Jungano. (Jungano, Compt. rend. Soc. Biol., Paris, *65*, 1908–09, 716; *Bacillus sporogenes liquefaciens* Jungano, *ibid.*, 718; *Bacillus sporogenes non liquefaciens anaerobius* LeBlaye and Guggenheim, Man. Prat. d. Diag. Bact., 1914, 395.) From the intestine of the flying fox (*Pteropus*).

Bacillus sporogenes foetidus Choukévitch. (Ann. Inst. Past., *25*, 1911, 257.) From the large intestine of a horse.

Bacillus sporogenes parvus Choukévitch. (Ann. Inst. Past., *27*, 1913, 251.) From intestine of cattle.

Bacillus stellatus Vincent. (Vincent, Ann. Inst. Past., *21*, 1907, 69; *Bacillus stellatus anaerobius* LeBlaye and Guggenheim, Man. Prat. d. Diag. Bact., 1914, 368; *Bacterium stellatum* LeBlaye and Guggenheim, *idem.*) Anaerobic status uncertain, but Vincent compares it with *Bacillus polypiformis* Liborius, and with Anaerobe No. II, Sanfelice. From water.

Bacillus subfoetidus Migula. (Anaerobe V, Sanfelice, Ztschr. f. Hyg., *14*, 1893, 372; Migula, Syst. d. Bakt., *2*, 1900, 609; *Bacillus anaerobic No. V* Chester, Man. Determ. Bact., 1901, 296; *Bacillus pseudotetanicus* Chester, *ibid.*, 302.) From putrefying meat infusions, soil, and from animal excreta.

Bacillus tachysporus Wesbrook. (Jour. Path. and Bact., *4*, 1896–97, 8.) From infection in human tetanus.

Bacillus tenuis glycolyticus Distaso. (Ann. Inst. Past., *23*, 1909, 955.) From intestine of the flying fox (*Pteropus*).

Bacillus tenuis spatuliformis Distaso. (Distaso, Cent. f. Bakt., I Abt., Orig., *59*, 1911, 101; *Bacteroides tenuis* Bergey et al., Manual, 1st ed., 1923, 263; *Cillobacterium spatuliforme* Prévot, Ann. Inst. Past., *60*, 1938, 297; *Bacillus spatuliformis* Prévot, Man. d. Class., etc., 1940, 79.) Spores not observed by Distaso, but placed by him in the perfringens-group. From feces of dog.

Bacillus teras Knorr. (Knorr, Cent. f. Bakt., I Abt., Orig., *82*, 1918–19, 225; *Inflabilis teras* Prévot, Ann. Inst. Past., *61*, 1938, 77.) From soil and from fluid aspirated in hematopneumothorax.

Bacillus thalassophilus Russell. (Russell, Ztschr. f. Hyg., *11*, 1892, 189.) Variably recorded as a strict or facultative anaerobe (see *Bacillus polymyxa* and *Bacillus sphaericus*). From sea water and mud from depth of sea.

Bacillus thermofibrincolus Itano and Arakawa. (Bull. Agric. Chem. Soc., Japan, *5*, 1929, 33.) Source not recorded.

Bacillus tympani-cuniculi Morcos. (Jour. Bact., *23*, 1932, 454.) From viscera, muscles and blood of rabbits dying of infectious tympanitis.

Bacillus ukilii Weinberg, Prévot, Davesne and Renard. (Unnamed species of Ukil, Compt. rend. Soc. Biol., Paris, *87*, 1922, 1009; Weinberg et al., Ann. Inst. Past., *42*, 1928, 1199; *Bacillus oedematogenes* Frei, Ergeb. d. allgem. Path. Mensch. u. Tiere, *31*, 1936, 52; *Clostridium ukilii* Hauduroy et al., Dict. d. Bact. Path., 1937, 142; *Clostridium oedematis-benigni* Prévot, Ann. Inst. Past., *61*, 1938, 82; *Clostridium oedematis benigni* Prévot, Man. d. Class., etc., 1940, 120.) From diseased human appendix.

Bacillus ventriculosus Koch. (Koch, Botan. Zeit., *46*, 1888, 341; *Clostridium ventriculosus* Trevisan, I generi e le specie delle Batteriacee, 1889, 22.) Prob-

ably not anaerobic. Observed in decaying vegetation and in swampy waters.

Bacterium coprophilum Migula. (Anaerobe No. 2, Sewerin, Cent. f. Bakt., II Abt., *3*, 1897, 708; Migula, Syst. d. Bakt., *2*, 1900, 323; *Bacillus coprophilus* Weinberg, Nativelle and Prévot, Les Microbes Anaér., 1937, 643.) From horse manure.

Bacterium lini Migula. (Unnamed species of Winogradsky, Compt. rend. Acad. Sci., Paris, *121*, 1895, 744; Migula, Syst. d. Bakt., *2*, 1900, 513. From retting flax.

Bacterium pseudoclostridium Migula. (*Clostridium foetidum lactis* von Freudenreich, Cent. f. Bakt., II Abt., *1*, 1895, 856; Migula, Syst. d. Bakt., *2*, 1900, 511.) From cheese.

Bacterium sternbergii Migula. (*Bacillus anaerobicus liquefaciens* Sternberg, Researches relating to the etiology and prevention of yellow fever, Washington, 1891, 214; *Bacillus anaerobius liquefaciens* Kruse, in Flügge, Die Mikroorg., 3 Aufl., *2*, 1896, 241; Migula, Syst. d. Bakt., *2*, 1900, 444; *Bacterium anaerobicum* Chester, Man. Determ. Bact., 1901, 198.) From intestine of a yellow fever cadaver.

Bactridium butyricum Chudiakow. (Chudiakow, Zur Lehre von der Anaerobiose, Teil I, Moskau, 1896, (?); quoted from Rothert, Cent. f. Bakt., II Abt., *4*, 1898, 390.) Stated by Rothert to be a pathogenic, obligate anaerobe, but source of culture is not specified.

Caduceus thermophilus α Prévot. (Anaerobie thermophile α (Thermo α), Veillon, Ann. Inst. Past., *36*, 1922, 428; Prévot, Ann. Inst. Past., *61*, 1938, 86; *Bacillus thermophilus* α Prévot, Man. d. Class., etc., 1940, 150; *Caduceus thermophilus* Prévot, *ibid.*, 149; *Caduceus thermophilus alfa* Prévot, *ibid.*, 150.) From horse manure.

Clostridium aceticum Wieringa. (Jour. Microbiol. and Serol., *6*, 1940, 257.) From soil. Oxidizes H_2, using CO_2 as the hydrogen acceptor, forming acetic acid, thus using H_2 as sole source of growth energy and CO_2 as sole carbon source for cell growth.

Clostridium albo-lacteum Killian and Fehér. (Ann. Inst. Past., *55*, 1935, 620.) From Sahara Desert soil.

Clostridium alboluteum Killian and Fehér. (Ann. Inst. Past., *55*, 1935, 595.) From Sahara Desert soil.

Clostridium album liquefaciens Killian and Fehér. (Ann. Inst. Past., *55*, 1935, 595.) From Sahara Desert soil.

Clostridium album minor Killian and Fehér. (Ann. Inst. Past., *55*, 1935, 620.) Presumably identical with *Clostridium minor* Killian and Fehér, *ibid.*, 597. From Sahara Desert soil.

Clostridium album non liquefaciens Killian and Fehér. (Ann. Inst. Past., *55*, 1935, 599.) Presumably identical with *Clostridium non liquefaciens* Killian and Fehér, *ibid.*, 597. From Sahara Desert soil.

Clostridium americanum Pringsheim. (Eine Alkohole bildende Bakterienform, Pringsheim, Cent. f. Bakt., II Abt., *15*, 1906, 300; *Bacillus pringsheim* Pringsheim, *ibid.*, 311; Pringsheim, Cent. f. Bakt., II Abt., *16*, 1906, 796; *Clostridium butyricum* var. *americanum* Prévot, Man. d. Class., etc., 1940, 109.) Anaerobic status uncertain. From spontaneously fermenting potato.

Clostridium aurantibutyricum Hellinger. (Commemorative Vol. to Dr. Ch. Weizmann's 70th Birthday, Nov., 1944, 46.) From retted *Hibiscus* from So. Africa.

Clostridium balaenae Prévot. (Walfischseptikämie Bacillus, Nielsen, Cent. f. Bakt., *7*, 1890, 269; Bacille de la septicémie des baleines, Christiansen, Compt. rend. Soc. Biol., Paris, *83*, 1920, 324; Walfischseptikämiebazillus, Christiansen, Cent. f. Bakt., I Abt., Orig., *84*, 1920, 127; Prévot, Ann. Inst. Past., *61*, 1938, 81.) From flesh of whales dying of septicemia. Later isolated from same material by Christiansen.

Clostridium canadiense Dernby and Blanc. (Jour. Bact., *6*, 1921, 420.) From a human case of gangrene.

Clostridium caproicum Prévot. (*Ba-*

cillus anaerobicus der Capronsäuregruppe, Rodella, Cent. f. Bakt., II Abt., *16*, 1906, 58; Prévot, Ann. Inst. Past., *61*, 1938, 84; *Bacillus anaerobicus caproicus* Prévot, Man. d. Class., etc., 1940, 140.) From cheese.

Clostridium cellobioparus Hungate. (Jour. Bact., *48*, 1944, 499.) From rumen of cattle.

Clostridium cellulosae Horowitz-Wlassowa and Novotelnow. (Cent. f. Bakt., II Abt., *91*, 1935, 477.) Cited only by name. Source not stated.

Clostridium corallinum Prévot and Raynaud. (Ann. Inst. Past., *70*, 1944, 182.) From serous fluid obtained post mortem from a mouse inoculated with an emulsion of street dust.

Clostridium cuniculi Galli. (Galli, Boll. Ist. Sieroter., Milan, *3*, 1923–24, 337; *Clostridium gallii* Prévot, Ann. Inst. Past., *61*, 1938, 83.) From necrotic visceral lesion in a rabbit.

Clostridium disporum Vuillemin. (Compt. rend. Acad. Sci., Paris, *136*, 1903, 1583.) Probably not anaerobic. Encountered in cultures of *Blastomyces;* said to form two spores.

Clostridium foetidum fecale Romanovitch. (Compt. rend. Soc. Biol., Paris, *71*, 1911, 238.) From normal human intestine.

Clostridium ghoni Prévot. (Unnamed species of Ghon and Mucha, Cent. f. Bakt., I Abt., Orig., *39*, 1905, 497; Prévot, Ann. Inst. Past., *61*, 1938, 83.) From post-operative human peritonitis.

Clostridium giganteum Benecke and Keutner. (Ber. d. Deutsch. Botan. Gesellsch., *21*, 1903, 340.) From sea water.

Clostridium haemolysans Hauduroy et al. (*Bacillus anaerobius haemolysans* Markoff, Cent. f. Bakt., I Abt., Orig., *77*, 1915–16, 421; Hauduroy et al., Dict. d. Bact. Path., 1937, 105; *Plectridium hemolysans* Prévot, Ann. Inst. Past., *61*, 1938, 87.) From putrid human buccal tissues.

Clostridium hueppei Trevisan. (Buttersäurebacillen, Hueppe, Mitteil. a. d. kais. Gesundhts., *2*, 1884, 353; *Bacillus butyricus* Flügge, Die Mikroorg., 2 Aufl., 1886, 300; Trevisan, I generi e le specie delle Batteriacee, 1889, 22; *Bacillus pseudo-butyricus* Kruse, in Flügge, Die Mikroorg., 3 Aufl., *2*, 1896, 207; *Bacillus hueppei* Chester, Man. Determ. Bact., 1901, 276.) From milk.

Clostridium hyalinum Killian and Fehér. (Ann. Inst. Past., *55*, 1935, 595.) From Sahara Desert soil.

Clostridium kluyverii Barker and Taha. (Jour. Bact., *43*, 1942, 347.) From alcohol-containing enrichment cultures of *Methanobacterium omelianskii* inoculated with black mud from fresh water and marine sources.

Clostridium liborii Trevisan. (Liborius buttersäurebildender Bacillus, Flügge, Die Mikroorg., 2 Aufl., 1886, 299; Trevisan, I generi e le specie delle Batteriacee, 1889, 22.) Presumably the same as *Clostridium foetidum* Liborius, Ztschr. f. Hyg., *1*, 1886, 160. From mice inoculated with garden soil.

Clostridium medium Henneberg. (Cent. f. Bakt., II Abt., *55*, 1922, 248.) From human and animal feces.

Clostridium mitelmani Prévot. (Ann. Inst. Past., *61*, 1938, 84.) Stated by Prévot to have been isolated by Mitelman from diarrheal human intestine.

Clostridium mucosus Simola. (Simola, Ann. Acad. Scient. Fennicoe, Helsinki, Ser. A, *34*, 1931, (115?); *Clostridium mucosum* Prévot, Man. d. Class., etc., 1940, 112; not *Clostridium mucosum* Bergey et al., Manual, 4th ed., 1934, 472; quoted from Prévot, Ann. Inst. Past., *61*, 1938, 80 who records it as a facultative anaerobe.) Source of isolation unknown.

Clostridium myxogenes Simola. (Simola, Ann. Acad. Scient. Fennicoe, Helsinki, Ser. A, *34*, 1931, (115?); quoted from Prévot, Ann. Inst. Past., *61*, 1938, 80 who records it as a facultative anaerobe.) Source of isolation unknown.

Clostridium necrosans Prévot. (*Bacillus aerogenes necrosans* Schupfer, Policlin., Sez. Med., *12*, 1905, 261; Prévot, Ann. Inst. Past., *61*, 1938, 84.) Isolated

from a gaseous, necrotic thoracic abscess in a woman.

Clostridium nothnageli Henneberg. (Cent. f. Bakt., II Abt., *55*, 1921–22, 245.) Cultivated, but not isolated in pure culture, from human and animal feces.

Clostridium partum Prévot. (Unnamed anaerobe of Levens, Cent. f. Bakt., I Abt. Orig., *88*, 1922, 479; Prévot, Ann. Inst. Past., *61*, 1938, 85.) From a cow in post-partum rausch-brand.

Clostridium propionicum Cardon and Barker. (Jour. Bact., *52*, 1946, 629.) From marine mud.

Clostridium proteolyticum Choukévitch. (Ann. Inst. Past., *27*, 1913, 253.) Said to be a facultative anaerobe. From intestine of cattle.

Clostridium pygmaeum Henneberg. (Cent. f. Bakt., II Abt., *55*, 1921–22, 250.) From human and animal feces.

Clostridium sarcoemphysematodes Prévot. (*Bacillus sarcemphysematodes hominis* Conradi and Bieling, Münch. med. Wochnschr., *63*, 1916, 134; *Clostridium sarcemphysematodes* (sic) Prévot, Ann. Inst. Past., *61*, 1938, 81; Prévot, Man. d. Class., etc., 1940, 120.) From human gaseous gangrene.

Clostridium sardiniensis Prévot. (Ann. Inst. Past., *61*, 1938, 81.) Referred to Altara by Prévot. Cited by name only from Prévot.

Clostridium secundum Hauduroy et al. (Unnamed species of Ghon and Sachs, Cent. f. Bakt., I Abt., Orig., *48*, 1909, 399; Hauduroy et al., Dict. d. Bact. Path., 1937, 130.) From human emphysematous liver.

Clostridium solidum Sanfelice. (Sanfelice, Ztschr. f. Hyg., *14*, 1893, 372; *Bacillus solidum* Chester, Ann. Rept. Del. Col. Agr. Exp. Sta., *10*, 1898, 129; *Bacillus sanfelicei* Migula, Syst. d. Bakt., *2*, 1900, 630; not *Bacillus solidus* Lüderitz, Ztschr. f. Hyg., *5*, 1889, 152.) From putrefying meat infusions, soil and from animal excreta.

Clostridium sphaeroides Killian and Fehér. (Ann. Inst. Past., *55*, 1935, 598.) From Sahara Desert soil.

Clostridium strasburgense Hauduroy et al. (Unnamed species of Vaucher, Boez, Lanzenberg and Kehlstadt, Bull. et Mem. Soc. Méd. Hôp. Paris, *49*, 1925, 1641; Hauduroy et al., Dict. d. Bact. Path., 1937, 135; *Inflabilis sanguicole* Prévot, Ann. Inst. Past., *61*, 1938, 77.) Isolated by blood culture in human puerperal septicemia.

Clostridium tenue Hauduroy et al. (*Bacillus anaerobicus tenuis* Distaso, Cent. f. Bakt., I Abt., Orig., *62*, 1912, 439; *Bacillus anaerobius tenuis* LeBlaye and Guggenheim, Man. Prat. d. Diag. Bact., 1914, 337; Hauduroy et al., Dict. d. Bact. Path., 1937, 136.) From normal human intestine.

Clostridium thermoacidophilus Damon and Feirer. (Damon and Feirer, Jour. Bact., *10*, 1925, 41; *Palmula thermoacidophila* Prévot, Ann. Inst. Past., *61*, 1938, 89; *Acuformis thermoacidophilus* Prévot, Man. d. Class., etc., 1940, 165.) Isolated anaerobically, but not strictly anaerobic. From horse manure.

Clostridium thermoaerogenes Damon and Feirer. (Damon and Feirer, Jour. Bact., *10*, 1925, 40; *Caduceus thermoaerogenes* Prévot, Ann. Inst. Past., *61*, 1938, 86.) From horse manure.

Clostridium thermocellum Viljoen, Fred and Peterson. (Viljoen et al., Jour. Agric. Sci. (London), *16*, 1926, 7; *Terminosporus thermocellus* Prévot, Ann. Inst. Past., *61*, 1938, 86.) From horse manure.

Clostridium thermochainus Damon and Feirer. (Jour. Bact., *10*, 1925, 42.) From horse manure.

Clostridium thermophilum Jemel'jantschik and Borissowa. (Microbiology (Russian), *10*, 1941, 236–241; *Bacillus thermophilus anaerobicus, idem;* abst. in Cent. f. Bakt., II Abt., *105*, 1942, 148; not *Clostridium thermophilum* Pribram, Jour. Bact., *22*, 1931, 430.) From fish conserves.

Clostridium thermoputrificum Damon and Feirer. (Damon and Feirer, Jour. Bact., *10*, 1925, 39; *Palmula thermopu-*

trifica Prévot, Ann. Inst. Past., *61*, 1938, 89; *Acuformis thermoputrificus* Prévot, Man. d. Class., etc., 1940, 165.) From horse manure.

Clostridium toxinogenes Prévot. (Unnamed anaerobe of Kojima, Ztschr. f. Hyg., *99*, 1923, 86; Prévot, Ann. Inst. Past., *61*, 1938, 82.) From muscle of a cow dying of symptomatic anthrax.

Clostridium ureolyticum Prévot. (Ann. Inst. Past., *61*, 1938, 85; presumably Erde A, Geilinger, Cent. f. Bakt., II Abt., *47*, 1917, 252.) From manured soil.

Clostridium valerianicum Prévot. (Fäulnisanaerobien der Baldriansäure, Rodella, Cent. f. Bakt., II Abt., *16*, 1906, 62; Prévot, Ann. Inst. Past., *61*, 1938, 84.) From cheese.

Clostridium viscosum Chudiakow. (Zur Lehre von der Anaerobiose, Teil I, 1896 (Russ.); quoted from Rothert, Cent. f. Bakt., II Abt., *4*, 1898, 390.) A facultative anaerobe.

Clostridium xanthogenum DeGraaff. (Nederl. Tijd. Hyg., Microbiol. en Serol., *4*, 1930, 219.) From cultured buttermilk undergoing atypical fermentation.

Clostridium zuntzii Henneberg. (Cent. f. Bakt., II Abt., *55*, 1922, 249.) Cultivated, but not isolated in pure culture, from human and animal feces.

Cornilia parva Trevisan. (*Bacillus liquefaciens parvus* Lüderitz, Ztschr. f. Hyg., *5*, 1889, 148; Trevisan, I generi e le specie delle Batteriacee, 1889, 22; *Bacterium parvum* Migula, Syst. d. Bakt., *2*, 1900, 324.) From animals inoculated with garden soil.

Endosporus otricolare Prévot. (Bacillo otricolare, Nacciarone, Riforma Med., Napoli, *33*, 1917, 778; Prévot, Ann. Inst. Past., *61*, 1938, 75.) From gangrenous war wounds.

Granulobacillus sporogenes Andre. (*Granulobacillus sp.*, Sommer, Deutsch. Monatschr. f. Zahnheilk., *33*, 1915, 328; Andre, Ztschr. f. Hyg., *114*, 1933, 412.) From infected, necrotic pulp of human teeth.

Granulobacter lactobutyricum Beijerinck. (Ferment de lactate de chaux, Pasteur, Compt. rend. Acad. Sci., Paris, *56*, 1863, 416; Beijerinck, Verhandl. d. k. Akademie v. Wetensch., Amsterdam, Tweedie Sectie, Deel I, 1893, 8; *Bacillus lactobutyricus* Migula, Syst. d. Bakt., *2*, 1900, 601; *Amylobacter lactobutyricus* van Beynum and Pette, Cent. f. Bakt., II Abt., *93*, 1935, 200.) From fermenting grain mash and from soil.

Granulobacter pectinovorum Beijerinck and van Delden. (*Plectridium pectinovorum* Störmer, Mitteil. d. deutsch. Landwirts. Gesellsch., *18*, 1903, 195; Beijerinck and van Delden, Arch. Néerl. d. Sci. Exactes et Nat., Ser. II, *9*, 1904, 423; *Bacillus pectinovorus* LeBlaye and Guggenheim, Man. Prat. d. Diag. Bact., 1914, 324; *Bacillus pectinovorum* Henneberg, Cent. f. Bakt., II Abt., *55*, 1922, 279; *Clostridium pectinovorum* Donker, Thesis, Delft, 1926, 145.) From retting plant tissues.

Granulobacter reptans Beijerinck and van Delden. (Cent. f. Bakt., II Abt., *9*, 1902, 13.) Probably aerobic or microaerophilic. From garden and other soils.

Granulobacter sphaericum Beijerinck. (Cent. f. Bakt., II Abt., *7*, 1901, 568.) Probably aerobic or microaerophilic. From garden and other soils.

Granulobacter urocephalum Beijerinck and van Delden. (Arch. Néerl. d. Sci. Exactes et Nat., Ser. II, *9*, 1904, 423.) From retting plant tissues.

Hiblerillus rectus Heller. (*Streptobacillus anaerobicus rectus* Choukévitch, Ann. Inst. Past., *25*, 1911, 350; *Bacillus anaerobius rectus* LeBlaye and Guggenheim, Man. Prat. d. Diag. Bact., 1914, 337; Heller, Jour. Bact., *7*, 1922, 17; *Inflabilis rectus* Prévot, Ann. Inst. Past., *61*, 1938, 77.) From large intestine of the horse.

Hiblerillus septimus Heller. (Art VII, von Hibler, Untersuch. ü. d. Path. Anaer., 1908, 3 and 406; Heller, Jour. Bact., *7*, 1922, 17; *Clostridium septimum* Prévot, Ann. Inst. Past., *61*, 1938, 84.) From spleen of a guinea pig inoculated with soil.

Inflabilis barati Prévot. (Bacille de Barat, Tissier, Compt. rend. Soc. Biol., Paris, *81*, 1918, 426; Prévot, Ann. Inst. Past., *61*, 1938, 77.) From beer wort.

Inflabilis magnus Prévot. (*Streptobacillus anaerobicus magnus* Choukévitch, Ann. Inst. Past., *25*, 1911, 251; *Bacillus anaerobius magnus* LeBlaye and Guggenheim, Man. Prat. d. Diag. Bact., 1914, 337; Prévot, Ann. Inst. Past., *61*, 1938, 77.) From large intestine of the horse.

Inflabilis plagarum Prévot. (Bacillus S, Adamson, Jour. Path. and Bact., *22*, 1918–19, 373; Prévot, Ann. Inst. Past., *61*, 1938, 77.) From war wounds.

Inflabilis pseudo-perfringens Prévot. (Presumably Bacillus L, Adamson, Jour. Path. and Bact., *22*, 1918–19, 372; Prévot, Ann. Inst. Past., *61*, 1938, 77.) From war wounds.

Inflabilis setiensis Prévot and Raynaud. (Ann. Inst. Past., *70*, 1944, 50.) From oysters.

Martellillus proteolyticus Heller. (Organism II, Hempl, Jour. Hyg., *17*, 1918, 16; Heller, Jour. Bact., *7*, 1922, 26.) From muscle in human gaseous gangrene.

Myerillus sadowa Heller. (Jour. Bact., *7*, 1922, 7; also Barney and Heller, Arch. Surg., *4*, 1922, 477.) From a gangrenous human arm.

Pectinobacter amylophilum Makronov. (Arch. Sci. Biol. (Russ.), *18*, 1915, 441.) Stated by author to be anaerobic, but description does not make this evident. From soil.

Plectridium cellulolyticum Pochon. (Compt. rend. Soc. Biol., Paris, *113*, 1933, 1325.) Isolated anaerobically, but not strictly anaerobic. From stomach of ruminants.

Plectridium pectinovorum liquefaciens Sjolander and McCoy. (Cent. f. Bakt., II Abt., *97*, 1937, 315 and 322; probably identical with *Amylobacter liquefaciens* Ruschmann and Bavendamm, Cent. f. Bakt., II Abt., *64*, 1937, 359.) From spontaneously retting plant tissues.

Plectridium snieszkoi Prévot. (Unnamed anaerobic thermophilic cellulose-fermenting species, Snieszko, Cent. f. Bakt., II Abt., *88*, 1933, 403; Prévot, Man. d. Class., etc., 1940, 154.) From soil and manure.

Recordillus fragilis Heller. (Jour. Bact., *7*, 1922, 8 and 27.) From a liver infarct in a cow.

Reglillus progrediens Heller. (Jour. Bact., *7*, 1922, 7; also Barney and Heller, Arch. Surg., *4*, 1922, 477.) From muscle of a gangrenous human arm.

Robertsonillus primus Heller. (Organism I, Hempl, Jour. Hyg., *17*, 1918, 13; Heller, Jour. Bact., *7*, 1922, 7.) From a gangrenous war wound of human maxilla.

Streptobacillus terrae Ucke. (Cent. f. Bakt., I Abt., *23*, 1898, 1000.) From garden soil.

Terminosporus raabi Prévot. (Unnamed anaerobe of Raab, Jour. Amer. Water Works Assoc., *10*, 1923, 1051; Prévot, Ann. Inst. Past., *61*, 1938, 86). From Minneapolis city water.

Terminosporus thermocellulolyticus Pochon. (Ann. Inst. Past., *68*, 1942, 354, 383 and 467.) Strict anaerobe. Optimum growth at 60° to 66°C.

Tyrothrix catenula Duclaux. (Duclaux, Ann. Inst. Nat. Agron., *4*, 1882, 23; *Cornilia catenula* Trevisan, I generi e le specie delle Batteriacee, 1889, 22; *Bacillus catenula* Chester, Ann. Rept. Del. Col. Agr. Exp. Sta., *10*, 1898, 123.) Commonly regarded as anaerobic, but not by Migula (Syst. d. Bakt., *2*, 1900, 588). From cheese.

Tyrothrix claviformis Duclaux. (Duclaux, Ann. Inst. Nat. Agron., *4*, 1882, 23; *Pacinia claviformis* Trevisan, *in litt.*, quoted from DeToni and Trevisan, in Saccardo, Sylloge Fungorum, *8*, 1889, 1017; *Bacterium claviforme* Migula, Syst. d. Bakt., *2*, 1900, 322; *Bacillus claviformis* Vincent, Ann. Inst. Past., *21*, 1907, 70.) From cheese.

Tyrothrix urocephalum Duclaux. (Duclaux, Ann. Inst. Nat. Agron., *4*, 1882, 23; *Bacterium urocephalum* Chester, Ann. Rept. Del. Col. Agr. Exp. Sta., *10*, 1898, 123; *Bacillus urocephalum* Migula, Syst. d. Bakt., *2*, 1900, 588.)

Appendix II. The following organisms are listed in the text as probable synonyms or possibly related species. They are cited here again in order to record the source of the original isolation. For convenience, they are listed alphabetically under the names of the species to which such presumed relationship is ascribed.

1. **Clostridium butyricum** Prazmowski.

Amylobacter non liquefaciens Ruschmann and Bavendamm. From retting plant tissues.

Bacille amylozyme, Perdrix. From city water of Paris, and from the Seine River water.

Bacillus amylobacter S and *W* Wertheim. From soil and tissues of field plants.

Bacillus butylicus Fitz. From glycerol solutions undergoing butylic fermentation after inoculation with fresh cow feces.

Bacillus holobutyricus Perdrix. From putrefying milk.

Bacillus orthobutylicus Grimbert. From soil, grains and from legumes.

Bacillus saccharobutyricus von Klecki. From cheese.

Bacterium navicula Reinke and Berthold. Observed and described from decomposing plant tissues. Not isolated in pure culture.

Bactridium butyricum Chudiakow. Cited by Rothert, and source not stated by abstractor.

Butylbacillus, Buchner. From glycerinated hay infusion.

Clostridium butyricum (*Bacillus amylobacter*) I, II, III, Gruber. From sugar solutions undergoing butyric fermentation. Source of inoculum not stated. (III is probably not strictly anaerobic.)

Clostridium butyricum iodophilum Svartz. From human feces.

Clostridium intermedium Donker. From retting flax.

Clostridium polyfermenticum Partansky and Henry. From mud of streams and lakes and from soil.

Clostridium saccharobutyricum Donker. From various farinaceous materials and from soil.

Clostridium saccharopetum Partansky and Henry. From mud of streams and lakes and from soil.

Clostridium saccharophilicum Partansky and Henry. From mud of streams and lakes and from soil.

Clostridium saccharopostulatum Partansky and Henry. From mud of streams and lakes and from soil.

Clostridium tyrobutyricum van Beynum and Pette. From soil, water, milk, cheese and various farinaceous materials. Widely dispersed in nature.

Ferment butyrique (Vibrion butyrique) Pasteur. Cultivated and presumably isolated from sugar solutions undergoing butyric fermentation after inoculation with yeast. Purity of cultures seriously questioned.

Granulobacillus saccharobutyricus mobilis non-liquefaciens Schattenfroh and Grassberger. From milk and from soil.

Granulobacter butylicum Beijerinck. From fermenting grain mash and from soil.

Granulobacter saccharobutyricum Beijerinck. From fermenting grain mash and from soil.

Granulobacter saccharobutyricus immobile nonliquefaciens McCoy et al. Source of isolation not recorded.

Plectridium pectinovorum Störmer. From retting flax and hemp. Probably not strictly anaerobic.

1b. **Clostridium pasteurianium** Winogradsky.

Bacillus azoticus, *Bacillus dulcitofermentans*, *Bacillus inulofugus*, *Bacillus nonpentosus* and *Bacillus rhamnoticus* Bodily. Source of isolation not specified, other than from cultures received from various sources labeled *C. pasteurianum*.

6. **Clostridium septicum** Ford.

Bacillus tumefaciens Wilson. From human gaseous gangrene.

Bradsotbacillus, Nielsen. From tissues and organs of sheep dying of braxy.

Walfischseptikämie Bacillus, Nielsen. From whales evidently dead of septicemia resulting from harpoon wounds.

9. **Clostridium novyi** Bergey et al.

Bacille neigeux, Jungano. From a human case of fetid cystitis, from abscess of kidney, and from various perineal infections.

Bacillus bellonensis Sacquépée. From human gaseous gangrene.

Bacillus gigas Zeissler and Rassfeld. From tissues of a sheep dying of a braxy-like disease.

Bacillus oedematiens Weinberg and Seguin. From human gaseous gangrene.

Clostridium bubalorum Prévot. Isolated, but not named, by Kraneveld from cases of osteomyelitis of the East Indian buffalo.

Gasödembazillus, Aschoff. From human gaseous edema resulting from war wounds.

11. **Clostridium acetobutylicum** McCoy et al.

Bacillus butylaceticum Freiberg. From grains, soil and natural waters. Widely distributed in nature.

Bacillus butylicus B. F., Ricard. From drains from slaughter houses.

Bacillus saccharobutyricus liquefaciens McCoy et al. Source of isolation unknown; records only from the collection of the Dept. Agric. Bact. of the Univ. of Wis. Received from a commercial laboratory.

Butylobacter betae Bakonyi. From beets (*Beta vulgaris*) contaminated with soil.

Butylobacter sinense Bakonyi. From Jaffa oranges.

Butylobacter solani Bakonyi. From German potatoes.

Butylobacter zeae Bakonyi. From Hungarian maize.

Clostridium butyricum (*Prazmowski-Pike-Smyth*) Pike and Smyth. From spontaneously fermenting corn meal mash.

Clostridium inverto-acetobutylicum Legg and Stiles. From soil and from plant materials in contact with soil.

Clostridium propyl-butylicum Muller and Legg. From soil and from plant materials in contact with soil.

Clostridium saccharo-acetobutylicum Stiles and Legg. From soil and from plant materials in contact with soil.

Clostridium saccharo-acetobutylicum-alpha McCoy. From soil.

Clostridium saccharo-acetobutylicum-beta Arzberger. From soil, rotten wood, grain, cornstalks and river mud.

Clostridium saccharo-acetobutylicum-gamma Arzberger. From soil, rotten wood, grain, corn stalks and river mud.

Clostridium saccharobutyl-acetonicum Loughlin. From potato; found in soil and on plant materials grown in or near soil.

Clostridium saccharobutylicum-gamma Izsak and Funk. From rice.

Clostridium saccharobutyl-isopropyl-acetonicum Loughlin. From potatoes, grains and other plant materials grown in or above soil.

Clostridium (Bacillus) tetrylium Owen, Mobley and Arroyo. From soil and from roots of sugar cane.

13. **Clostridium sporogenes** Bergey et al.

Bacillus putrificus verrucosus Zeissler. From animals suffering from a Rauschbrandlike infection; later from gangrenous war wounds.

Bacillus saprogenes carnis Salus. From human feces by enrichment in meat mash medium.

Bacillus sporogenes coagulans Debono. From normal human intestine.

Paraplectrum foetidum Weigmann. From cheese and milk.

Reading Bacillus, Donaldson and Joyce. From gangrenous human war wounds.

20. **Clostridium bifermentans** Bergey et al.

Bacillus centrosporogenes Hall. From a sterility test of tuberculin, from canned spinach and from garden soil.

Bacillus liquefaciens magnus Lüderitz. From mice and guinea pigs inoculated with garden soil.

Bacillus nonfermentans Hall and Whitehead. From poisoned African arrowheads.

Bacillus oedematis sporogenes Sordelli. From human gaseous gangrene.

Bacillus putrificus tenuis Zeissler. From malignant edema of various animals and from human gaseous gangrene.

Bacillus sporogenes foetidus Chouké-vitch. From large intestine of horse.

Clostridium foetidum Liborius. From mice inoculated with garden soil.

Clostridium foetidum carnis Salus. From human feces by enrichment in meat mash medium.

Clostridium oedematoides Meleney, Humphreys and Carp. From a case of human post-operative gaseous gangrene.

24. **Clostridium perfringens** Holland.

Bacille du rhumatisme, Achalme. Isolated by blood culture from human cases of acute articular rheumatism.

Bacillus amylobacter immobilis Gratz and Vas. From Liptauer cheese.

Bacillus cadaveris Sternberg. From liver and kidney of a yellow fever cadaver.

Bacillus cadaveris butyricus Buday. From organs of human cadavers undergoing postmortem emphysema.

Bacillus egens Stoddard. From muscle in a fatal case of human gaseous gangrene.

Bacillus emphysematis maligni Wicklein. From human gaseous gangrene.

Bacillus emphysematis vaginae Lindenthal. From human kolpohyperplasia cystica or vaginitis emphysematosa.

Bacillus multiformis Distaso. From feces of dog.

Bacillus ovitoxicus Bennetts. From blood, tissues and organs of sheep in Australia dying of entero-toxemia.

Bacillus paludis McEwen. From intestines and viscera of sheep in the Romney Marsh in England suffering from a disease called struck.

Bacillus perfringens Veillon and Zuber. Originally isolated from pus in human appendicitis; later from a variety of sources.

Bacillus phlegmones emphysematosae Fraenkel. From human gaseous phlegmons; later from a variety of related conditions of human beings and animals.

Bacillus zoodysentriae hungaricus Detre. Isolated in Hungary from intestines of diarrheal pigs and lambs.

Clostridium perfringens var. *anaerogenes* Hauduroy et al. An unnamed culture isolated by Grooten by blood culture from a fatal human septicemia.

Granulobacillus saccharobutyricus immobilis liquefaciens Schattenfroh and Grassberger. Originally isolated from market milk; later from cheese, soil, water, human and animal feces, and from various grain meals.

29. **Clostridium paraputrificum** Snyder.

Bacillus innutritus Kleinschmidt. From stools of newborn infants.

Plectridium fluxum Prévot. From feces of nursing newborn infants.

Plectridium nonum Prévot. From emphysematous muscle of an amputated human arm.

41. **Clostridium lentoputrescens** Hartsell and Rettger.

Bacillus cadaveris sporogenes (*anaerobicus*) Klein. From normal intestines of man and animals.

Bacillus radiatus Lüderitz. From mice and guinea pigs inoculated with garden soil.

Bacillus tetanoides (*B*) Adamson. From human septic and gangrenous war wounds.

43. **Clostridium tetanomorphum** Bergey et al.

Bacillus fragilis Veillon and Zuber. From human cases of purulent appendicitis.

Bacillus ramosus Veillon and Zuber. From human cases of purulent appendicitis and from pulmonary gangrene.

45. **Clostridium angulosum** Hauduroy et al.

Bacillus angulosus Garnier and Simon. From blood of a child suffering from typhoid fever.

61. **Clostridium tertium** Bergey et al. *Bacillus aero-tertius* Bulloch et al. Isolated from gangrenous human war wounds. Stated to be aerobic.

Bacillus gazogenes parvus Choukévitch. From large intestine of horse.

Bacillus spermoide Ninni. From soil.

Suborder II. Caulobacteriineae Breed, Murray, and Hitchens.*

(*Caulobacteriales* Henrici and Johnson, Jour. Bact., *29*, 1935, 3; *ibid.*, *30*, 1935, 83; Breed, Murray and Hitchens, Bact. Rev., *8*, 1944, 255.)

Non-filamentous, attached bacteria growing characteristically upon stalks, sometimes sessile. The stalked cells are asymmetrical in that gum, ferric hydroxide or other material is secreted from one side or one end of the cell to form the stalk. Multiply by transverse fission. In some species the stalks are very short or absent. In the latter case the cells may be attached directly to the substrate in a zoogloeic mass. Cells occur singly, in pairs or short chains, never in filaments; not ensheathed. Non-spore-forming. Typically aquatic in habitat.

Key to the families of suborder **Caulobacteriineae.**

I. Long axis of cell transverse to long axis of stalk; stalks dichotomously branched
  A. Stalks lobose, composed of gum, forming zoogloea-like colonies.
    Family I. *Nevskiaceae*, p. 830.
  B. Stalks are bands of ferric hydroxide.
    Family II. *Gallionellaceae*, p. 830.
II. Long axis of cell coincides with axis of stalk.
  A. Reproducing by transverse fission, stalks unbranched.
    Family III. *Caulobacteriaceae*, p. 832.
III. Sessile, capsulated colonies of cocci and short rods attached to water plants.
  A. Deposit of ferric hydroxide about a zoogloeic mass.
    Family IV. *Siderocapsaceae*, p. 833.

As a result of discussions that have taken place since the fifth edition of the Manual was issued, certain readjustments have been made in the arrangement of the stalked bacteria. The organisms in all of the typical species are simple rigid bacteria which are like ordinary bacteria except that they develop a stalk. For this reason the group has been made a suborder of the order *Eubacteriales*.

Stanier and Van Niel (Jour. Bact., *42*, 1941, 454) emphasize the fact that the family *Pasteuriaceae* includes species which reproduce by methods (longitudinal fission, budding) different from those found in other groups of bacteria, and Henrici and Johnson (*loc. cit.*, 81) state that it is at least doubtful whether these species are phylogenetically related to the other stalked bacteria. While waiting for pure culture studies and a clarification of these relationships, this family has been placed in an appendix to the suborder *Caulobacteriineae.*

The family *Siderocapsaceae* has been included in the suborder as the absence of a stalk in attached forms is a natural modification. As stated by Cholodny (Die Eisenbakterien, Jena, 1926, 34–58), these bacteria are similar in morphology and physiology to those found in the family *Gallionellaceae.* This is an arrangement that retains all of the simple non-filamentous types of iron bacteria in one general group.

The stalked bacteria studied by Henrici and Johnson (*loc. cit.*) were of fresh water origin. Bacteria of this type are found, however, equally if not more abundantly in marine habitats where they play their part in starting the fouling of underwater surfaces. ZoBell and Upham (Bull. Scripps Inst. Oceanography, La Jolla, Cali-

* Completely revised by Prof. A. T. Henrici, University of Minnesota, Minneapolis, Minnesota, December, 1938; further revision by Prof. Robert S. Breed, New York State Experiment Station, Geneva, New York, July, 1946.

fornia, *5*, 1944, 253) summarize this situation as follows: "Many of the bacteria found in sea water are sessile or periphytic, growing preferentially or exclusively attached to solid surfaces. The sessile habit of marine bacteria is most pronounced when they are growing in very dilute nutrient solutions such as sea water to which nothing has been added. . . . Most sessile bacteria appear to attach themselves tenaciously to solid surfaces by exuding a mucilaginous holdfast. A few have stalks. Some of the sessile bacteria grow on the walls of the culture receptacle without clouding the medium itself".

The emphasis placed on the presence of a stalk by Henrici and Johnson (*loc. cit.*) seems artificial. In fact it may be questioned whether mere attachment by a holdfast or otherwise is a character of fundamental importance from the taxonomic standpoint. Henrici and Johnson's arrangement of these poorly known bacteria, however, has certain practical advantages and it has therefore been retained in this edition of the MANUAL with such modifications as seem to be clearly indicated by the progress that has been made since their outline was published.

The submerged slide technique as employed by Henrici (Jour. Bact., *25*, 1933, 277) and by ZoBell and Allen (Proc. Soc. Exper. Biol. and Med., *30*, 1933, 1409) has proved to be most useful for studying bacteria that live attached to a substrate.

FAMILY I. NEVSKIACEAE HENRICI AND JOHNSON.

(Jour. Bact., *29*, 1935, 4; *ibid.*, *30*, 1935, 83.)

Stalked bacteria, the long axis of the rod-shaped cells being set at right angles to the axis of the stalk. Stalks lobose, dichotomously branched, composed of gum. Multiplication of cells by transverse binary fission. Growing in zoogloea-like masses in water or in sugar vats.

There is a single genus *Nevskia*.

Genus I. **Nevskia** *Famintzin.*

(Bul. Acad. Imp. Sci., St. Pétersb., *34*, N.S. *2*, 1892, 484.) From the Neva River at St. Petersburg.

Description as for the family.

The type species is *Nevskia ramosa* Famintzin.

1. **Nevskia ramosa** Famintzin. (Bul. Acad. Imp. Sci., St. Pétersb., Ser. IV, *34*, N.S. *2*, 1892, 484.) From Latin *ramosus*, branched.

Globular, bush-like or plate-like colonies of gummy consistency floating upon the surface of water. Colonies composed of gummy material arranged in dichotomously branched stalks arising from a common base, with the bacterial cells contained in the gum, a single cell at the tip of each stalk. At times cells are set free from the stalks to start new colonies.

Rod-shaped cells set with their long axis at right angles to the axis of the broad lobe-like stalk. Cells 2 by 6 to 12 microns, containing a number of highly refractile globules of fat or sulfur.

Multiplication by binary fission. Not cultivated on artificial media.

Source: From the aquarium in the Botanical Garden, St. Petersburg. Similar but smaller organisms found by Henrici and Johnson (Jour. Bact., *30*, 1935, 63) in a jar of water from the lily pond of the University of Minnesota greenhouse in Minneapolis.

Habitat: Water.

2. **Nevskia pediculata** (Koch and Hosaeus) Henrici and Johnson. (*Bacterium pediculatum* Koch and Hosaeus, Cent. f. Bakt., *16*, 1894, 225; Henrici and Johnson, Jour. Bact., *30*, 1935, 83.) From Latin *pediculus*, diminutive of *pes*, foot.

Composed of twisted, short, thick, sausage-like strands, often branched. These strands are stalks, composed of gum.

The cells occur at the tips of the stalks and are smaller than those of *Nevskia ramosa* and are without internal globules. Not cultivated.

This organism is very similar to, and may be identical with, the cultivated species described and named *Betabacterium vermiforme* by Mayer (Das Tibi-Konsortium. Thesis, Utrecht, 1938). See p. 362.

Source: Found growing in the syrup of a sugar refinery as zoogloeae.

FAMILY II. GALLIONELLACEAE HENRICI AND JOHNSON.

(Jour. Bact., *29*, 1935, 4; *ibid.*, *30*, 1935, 83.)

Stalked bacteria, the long axis of the rod-shaped cells being set at right angles to the axis of the stalks. Stalks are slender, twisted bands, dichotomously branched, composed of ferric hydroxide, completely dissolving in dilute hydrochloric acid. Multiplication of cells by transverse binary fission. Grow in iron-bearing waters.

There is a single genus *Gallionella*.

Genus I. **Gallionella** *Ehrenberg.*

(Ehrenberg, Die Infusionsthierchen, 1838, 166; not *Gaillonella* Bory de St. Vincent, Dict. Classique d'Hist. Nat., *4*, 1823, 393; *Gloeotila* Kützing, Phycologia Generalis, 1843, 245; *Didymohelix* Griffith, Ann. Mag. Nat. Hist., Ser. 2, *12*, 1853, 438; *Spirophyllum* Ellis, Cent. f. Bakt., II Abt., *19*, 1907, 502; *Nodofolium* Ellis, Proc. Roy. Soc. Edinburgh, *28*, Part 5, 1908, 339.) From an incorrect spelling of the algal genus name, *Gaillonella*.

Description as for the family.

The type species is *Gallionella ferruginea* Ehrenberg.

Key to the species of genus Gallionella.

I. Cells kidney-shaped; stalks branched.
  A. Stalks slender, spirally twisted.
    1. Cells small, stalks very slender.
      1. *Gallionella ferruginea.*
    2. Cells larger, stalks broader.
      2. *Gallionella major.*
  B. Stalks thick, not definitely in spirals.
      3. *Gallionella minor.*
II. Cells oval or round; stalks unbranched.
      4. *Gallionella corneola.*

1. **Gallionella ferruginea** Ehrenberg. (*Gaillonella ferruginea* Ehrenberg, Vorl. Mittheil. ü. d. wirkl. Vorkommenn fossiler Infusionen u. ihre grosse Verbreitung, Ann. Phys., Ser. 2, *8*, 1836, 217; Ehrenberg, Die Infusionsthierchen, 1838, 166; *Melosira ochracea* Ralfs, Ann. and Mag. Nat. His., Ser. 1, *12*, 1843, 351 (quoted from Buchanan, General Systematic Bacteriology, 1925, 363); *Gloeotila ferruginea* Kützing, Species Algarum, 1849, 363; *Didymohelix ferruginea* Griffith, Ann. Mag. Nat. Hist., Ser. 2, *12*, 1853, 438; *Gloeosphaera ferruginia* Rabenhorst, Alg. Mitteleur., no. 387; Hedwigia, *8*, no. 9, 1854, 43; *Melosira minutula* Breb., Alg. Fal., *5*, 42 (quoted from DeToni and Trevisan, see below); *Spirulina ferruginea* Kirchner, Algen, Kryptogamenflora v. Schlesien, *2*, 1, 1878, 250; *Spirochaete ferruginea* Hansgirg, Oestr. botan. Ztschr., no. 7–8, 1888, 5; *Spirillum ferrugineum* DeToni and Trevisan, in Saccardo, Sylloge Fungorum, *8*, 1889, 1007; *Chlamydothrix ferruginea* Migula, Syst. d. Bakt., *2*, 1900, 1031; *Spirophyllum ferrugineum* Ellis, Cent. f. Bakt., II Abt., *19*, 1907, 502; *Spirophyllum tenue*, *Nodofolium ferrugineum*, *Spirosoma ferrugineum* and *Spirosoma solenoide* Ellis, Proc. Roy. Soc. Edinburgh, *28*, Part 5, 1908, 341; also see Cent. f. Bakt., II Abt., *26*, 1910, 321; *Gallionella taeniata* Enderlein, Bakterien-Cyclogenie, Berlin and Leipzig, 1925, 252.) From Latin *ferruginus*, iron rust.

Kidney-shaped bacteria, the cells 0.5 by 1.2 microns, which secrete colloidal ferric hydroxide from the concave portion of the cell, forming band-like stalks. A rotatory motion of the cells gives rise to a spiral twisting of the stalks.

In the older studies, the stalks were described as the organism, the minute cells at the tip having been dislodged or at least overlooked. The cells lie at the tip of the stalk, and multiply by transverse binary fission. This gives rise to a dichotomous branching of the stalks. Stalks become very long and slender, with smooth edges.

Not cultivated in artificial media.

Habitat: Cool springs and brooks which carry reduced iron in solution.

2. **Gallionella major** Cholodny. (Trav. Station. biolog. du Dniepre Acad. des Sci. de l'Ukraine, Classe Sci. Phys. et Math., *3*, Livre 4, 1927.) From Latin *major*, larger.

Very similar to *Gallionella ferruginea*, but the cells are distinctly larger (1 by 3 microns), and, some cells failing to divide, reach a length of 7 microns or more. These form stalks of double the normal width.

The cells contain one or more vacuoles, apparently filled with an iron compound.

Source: Found in a spring in the Caucasus.

Habitat: Iron-bearing water.

3. **Gallionella minor** Cholodny. (Ber. d. deutsch. Bot. Ges., *42*, 1924, 35.) From Latin *minor*, smaller.

Cells as in *Gallionella ferruginea*, but stalks are shorter, thicker, encrusted with nodules of iron and not definitely band-like or twisted.

Habitat: Iron-bearing water.

4. **Gallionella corneola** Dorff. (Die Eisenorganismen, Pflanzenforschung, Heft 16, 1934, 25.) From Latin *corneolus*, a little horn.

Cells spherical or ellipsoidal, or lenticular in cross section, 0.5 by 2.5 to 3.0 microns.

Stalks short, unbranched, not spirally twisted, completely dissolving in dilute hydrochloric acid. Stalks slender at the base, expanded at the tip, slightly curved, 15 to 30 microns long, attached to the substrate by a holdfast, 3 to 8 stalks arising from a single holdfast.

Habitat: Iron-bearing water.

Appendix: Additional species of *Gallionella* have been described as follows:

Gallionella glomerata described by Naumann (Kungl. Svenska Vetenskapsakad. Handl., I, *62*, 1921, Part 4, 45) is not a valid species according to Cholodny (Die Eisenbakterien, Jena, 1926, 40). From the Aneboda region, Sweden.

Gallionella reticulosa Butkevich. (Ber. d. Wiss. Meeresinst. Moscow, *3*, 1928, 58 and 80.) From the White Sea.

Gallionella sideropous described by Naumann (Kungl. Svenska Vetenskapsakad. Handl., I, *62*, 1921, Part 4, 33) is not a valid species, according to Cholodny (Die Eisenbakterien, Jena, 1926, 39). From the Aneboda region, Sweden.

Gallionella tortuosa Butkevich. (Ber. d. wiss. Meeresinst. Moscow, *3*, 1928, 57 and 79.) From the Petschora Sea.

FAMILY III. CAULOBACTERIACEAE HENRICI AND JOHNSON.

(Jour. Bact., *29*, 1935, 4; *ibid.*, *30*, 1935, 83.)

Stalked bacteria, the long axis of the elongated cells coinciding with the long axis of the stalks. Stalks are slender, flagellum-like, often attached to the substrate by a button-like holdfast, unbranched. Multiplication of cells by transverse binary fission. The outermost cell of a pair may form a stalk before cell division is complete. Periphytic, growing upon submerged surfaces.

There is a single genus *Caulobacter*.

Genus I. Caulobacter *Henrici and Johnson.*

(Jour. Bact., *29*, 1935, 4; *ibid.*, *30*, 1935, 83.) From Latin *caulis*, stalk and *bacter*, a small rod.

Description as for the family.

The type species is *Caulobacter vibrioides* Henrici and Johnson.

1. **Caulobacter vibrioides** Henrici and Johnson. (Jour. Bact., *30*, 1935, 84.) From Latin, like a vibrio.

Cells elongated, curved, vibrio-like, with rounded ends, 0.7 to 1.2 by 2.0 to 2.5 microns.

Growing upon firm substrates in water. Not cultivated on artificial media.

Habitat: Water.

Appendix: Henrici and Johnson (Jour. Bact., *30*, 1935, 62) list the following as possibly belonging in this genus:

Bacillus flagellatus Omeliansky. (Jour. Microbiol. (Russian), *1*, 1914, 24.) Probably the same as the organism described by Jones (Henrici and Johnson, *loc. cit.*, 62).

Polar flagellate organism, Jones. (Cent. f. Bakt., II Abt., *14*, 1905, 459.) From water and sewage.

Vibriothrix tonsillaris Tunnicliff and Jackson. (Tunnicliff and Jackson, Jour. Inf. Dis., *46*, 1930, 12; see Henrici and Johnson, *loc. cit.*, 62.) From tonsil crypts. See p. 219 for a different viewpoint regarding this species.

Six additional types are figured but not named by Henrici and Johnson (*loc. cit.*, 84).

FAMILY IV. SIDEROCAPSACEAE PRIBRAM.

(Tribe *Siderocapseae* Buchanan, Jour. Bact., *2*, 1915, 615; Pribram, Jour. Bact., *18*, 1929, 377.)

Cells spherical or ovoid. Motile stages, if any, unknown. Not yet cultivated on artificial media. Thick capsules enclosing the cells become encrusted with ferric hydroxide. Attached to the surface of leaves and other parts of water plants.

Key to the genera of family **Siderocapsaceae.**

I. Cocci, occurring singly and in groups, and embedded in small irregular gelatinous masses.

Genus I. *Siderocapsa*, p. 833.

II. Coccobacteria, occurring in chains, and embedded in large gelatinous masses.

Genus II. *Sideromonas*, p. 834.

Genus I. **Siderocapsa** *Molisch.*

(Ann. Jard. Bot. Buitenzorg, 2 Sér., Supp. 3, 1909, 29; also Die Eisenbakterien, Jena, 1910, 11.) From Greek *sideros*, iron and Latin *capsa*, box.

One to many spherical to ovoid small cells embedded in a mass of capsular material surrounded by ferric hydroxide. Best recognized by staining with Schiff's reagent. Motility unknown. Grow attached to the surface of water plants.

The type species is *Siderocapsa treubii* Molisch.

1. **Siderocapsa treubii** Molisch. (Ann. Jard. Bot. Buitenzorg, 2 Sér., Supp. 3, 1909, 29; also Die Eisenbakterien, Jena, 1910, 11.) Named for Prof. Treub, the director of the tropical garden at Buitenzorg, Java.

Cocci: 0.4 to 0.6 micron in diameter embedded in zoogloeal masses surrounded by ferric hydroxide.

Deposit ferric hydroxide on the surfaces of water plants.

Source: Found attached to the roots, root hairs and leaves of water plants (*Elodea*, *Nymphaea*, *Sagittaria*, *Salvinia*, etc.).

Habitat: Widely distributed, on fresh water plants.

2. **Siderocapsa major** Molisch. (Ann. Jard. Bot. Buitenzorg, 2 Sér., Supp. 3, 1909, 29; also Die Eisenbakterien, Jena, 1910, 13.) From Latin *major*, larger.

Cells colorless, coccus-like short rods, 0.7 by 1.8 microns. A colony consists of 2 to 100 or more cells.

Similar to *Siderocapsa treubii*, except

that the cells are larger and the gelatinous capsule is less sharply defined.

Source: Isolated from *Spirogyra sp.*

Habitat: Epiphytic on fresh water plants.

Appendix: Two additional species have been placed in the genus *Siderocapsa* by later investigators:

Siderocapsa coronata Redinger. (Arch. f. Hydrobiol., *22*, 1931, 410.) From lake water. A free floating form.

Siderocapsa monoica Naumann. (Kungl. Svenska Vetenskapsakad. Handl., I, *62*, 1921, Part 4, 49; quoted from Cholodny, Die Eisenbakterien, Jena, 1926, 59.) Found on *Potamogeton natans* in Sweden. Cells occur singly.

Genus II. Sideromonas *Cholodny.*

(Ber. d. deutsch. Bot. Ges., *40*, 1922, 326; also Die Eisenbakterien, Jena, 1926, 55.) From Greek *sideros*, iron and *monas*, a unit.

Small cocci or coccobacteria which grow in chains in gelatinous masses containing ferric hydroxide attached to thread algae, generally of the genus *Conferva*.

The type species is *Sideromonas confervarum* Cholodny.

1. **Sideromonas confervarum** Cholodny. (Ber. d. deutsch. Bot. Ges., *40*, 1922, 326; also Die Eisenbakterien, Jena, 1926, 55; *Siderocystis confervarum* Naumann, quoted from Dorff, Die Eisenorganismen, Pflanzenforschung, Heft 16, 1934, 13.) From Latin, of the genus *Conferva*.

Coccobacteria: 0.5 to 0.6 by 0.8 to 0.9 micron, occurring in chains embedded in gelatinous masses, 10 to 100 microns in diameter. Chains become visible when the gelatinous mass is treated with formalin followed by dilute HCl, washed in water, and stained with gentian violet or carbol fuchsin. No motility observed.

Form deposits of ferric hydroxide in the gelatinous mass surrounding the bacteria.

Source: Found on the surface of thread algae in water containing iron salts.

Habitat: Widely distributed on fresh water green algae.

Appendix: Additional species of simple, sessile, non-filamentous bacteria which cause deposits of ferric hydroxide have been described. The majority are rod-shaped bacteria and resemble *Sideromonas*. The list follows:

Ferribacterium calceum Brussoff. (Brussoff, Cent. f. Bakt., II Abt., *48*, 1918, 208; *Siderobacter calceum* Naumann, Kungl. Svenska Vetenskapsakad. Handl., I, *62*, Part 4, 1921, 53 and 63; *Bacillus calceus* De Rossi, Microbiol. Agraria e Technica, Torino, 1927, 903.) From slime in drainage ditches at Aachen.

Ferribacterium duplex Brussoff. (Brussoff, Cent. f. Bakt., II Abt., *45*, 1916, 547; *Sideroderma duplex* Naumann, Kungl. Svenska Vetenskapsakad. Handl., I, *62*, Part 4, 1921, 53 and 63; *Bacterium duplex* De Rossi, Microbiol. Agraria e Technica, Torino, 1927, 903.) A non-motile, diplobacterium from water samples from Breslau (Schwentniger and Pirschamer).

Naumanniella minor Dorff. (Die Eisenorganismen, Pflanzenforschung, Heft 16, 1934, 21.) From iron-bearing spring water at Worms (Rhein).

Naumanniella neustonica Dorff. (Die Eisenorganismen, Pflanzenforschung, Heft 16, 1934, 20.) From Neuston on Tuefelsee near Freienwalde. Dorff (*loc. cit.*) indicates this species as the type for a new genus *Naumanniella*.

Siderobacter duplex Naumann. (Kungl. Svenska Vetenskapsakad. Handl., I, *62*, Part 4, 1921, 55.) From Aneboda region, Sweden.

Siderobacter lineare Naumann (*loc. cit.*, 55). From Aneboda region, Sweden. The type species of the genus *Siderobacter*.

Siderococcus communis Dorff. (Die Eisenorganismen, Pflanzenforschung, Heft 16, 1934, 11.) Widely distributed in Germany, Finland, Russia, Sweden, Czechoslovakia and the U. S. A.

Siderococcus limneticus Dorff (*loc. cit.*). From a swamp iron ore deposit. This is the type species of the genus *Siderococcus* Dorff (*loc. cit.*).

Siderocystis duplex Naumann. (Kungl. Svenska Vetenskapsakad. Handl., I, *62*, Part 4, 1921, 43.) From Aneboda region, Sweden.

Siderocystis minor Naumann (*loc. cit.*, 43). From Aneboda region, Sweden.

Siderocystis vulgaris Naumann (*loc. cit.*, 42). From Aneboda region, Sweden. The type species of the genus *Siderocystis*.

Sideroderma limneticum Naumann. (Kungl. Svenska Vetenskapsakad. Handl., I, *62*, Part 4, 1921, 32; *Ochrobium tectum* Perfiliev, Verh. d. Internat. Vereinigung f. theoret. u. angew. Limnologie, 1925, Stuttgart, 1927; quoted from Dorff, Die Eisenorganismen, Pflanzenforschung, Heft 16, 1934, 18.) From Aneboda region, Sweden. The type species of the genus *Sideroderma*. Perfiliev regards this species as type for a new genus, *Ochrobium*.

Sideroderma rectangulare Naumann (*loc. cit.*, 54). From Aneboda region, Sweden.

Sideroderma tenue Naumann (*loc. cit.*, 54). From Aneboda region, Sweden.

Siderothece major Naumann. (Kungl. Svenska Vetenskapsakad. Handl., I, *62*, Part 4, 1921, 17.) From Aneboda region, Sweden. The type species of the genus *Siderothece*.

Siderothece minor Naumann (*loc. cit.*, 17). From Aneboda region, Sweden.

APPENDIX TO SUBORDER CAULOBACTERIINEAE.

The family *Pasteuriaceae* included among the stalked bacteria by Henrici and Johnson (*loc. cit.*) has been placed in this appendix as the organisms belonging to the genera *Pasteuria* and *Blastocaulis* reproduce by methods of fission or budding, or both, that are different from the methods of reproduction found in other bacteria. Further information regarding the organisms in these genera is greatly needed.

FAMILY A. PASTEURIACEAE LAURENT EMEND. HENRICI AND JOHNSON.

(Laurent, Compt. rend. Acad. Sci., Paris, *3*, 1890, 754; Henrici and Johnson, Jour. Bact., *30*, 1935, 84.)

Stalked bacteria with spherical or pear-shaped cells; if cells are elongated, long axis of cell coincides with axis of stalk. Stalks may be very short or absent, but when present are usually very fine and at times arranged in whorls attached to a common holdfast. Cells multiply by longitudinal fission or by budding, or by both. Mostly periphytic, one species is parasitic.

Key to the genera of family **Pasteuriaceae.**

I. Stalks lacking, cells sessile.

Genus I. *Pasteuria*, p. 836.

II. Stalks long and slender, often in whorls.

Genus II. *Blastocaulis*, p. 836.

Genus I. **Pasteuria** *Metchnikoff.*

(Ann. Inst. Past., *2*, 1888, 166.) Named for Louis Pasteur, the French chemist and bacteriologist.

Pear-shaped cells attached to each other or to a firm substrate by holdfasts secreted at the narrow end, multiplying by longitudinal fission and by budding of spherical or ovoid cells at the free end.

The type species is *Pasteuria ramosa* Metchnikoff.

1. **Pasteuria ramosa** Metchnikoff. (Ann. Inst. Past., *2*, 1888, 465.) From Latin *ramosus*, branched.

Cells grow attached to each other in cauliflower-like masses, multiplying by longitudinal fission and by intracellular spores (?) which are extruded as bud-like bodies.

Habitat: Parasitic in the body cavities of *Daphnia pulex* and *Daphnia magna.*

Genus II. **Blastocaulis** *Henrici and Johnson.*

(Jour. Bact., *30*, 1935, 84.) From Greek *blastos*, bud, germ and Latin *caulis*, stalk.

Pear-shaped or globular cells attached to a firm substrate by long slender stalks with a holdfast at the base. Stalks may occur singly or may arise in clusters from a common holdfast. Growing on firm substrates in fresh water. Not cultivated on artificial media.

The type species is *Blastocaulis sphaerica* Henrici and Johnson.

1. **Blastocaulis sphaerica** Henrici and Johnson. (Jour. Bact., *30*, 1935, 84.) From Latin *sphaera*, sphere.

Cells spherical, multiplying characteristically by budding, often staining deeply at the free pole and faintly at the attached pole, 1 to 2 microns in diameter.

Habitat: Water.

Appendix: Henrici and Johnson (*loc. cit.*, 84) figure but do not name four additional types of these organisms which they regard as additional species belonging to this genus.

Stanier and Van Niel (Jour. Bact., *42*, 1941, 454) regard the following as belonging to this group:

Hyphomicrobium vulgare Stutzer and Hartleb. (Saltpeterpilz, Stutzer and Hartleb, Cent. f. Bakt., II Abt., *3*, 1897, 621; Stutzer and Hartleb, Untersuchungen über die bei der Bildung von Saltpeter beobachteten Mikroorganismen, I Abt. Mittheil. landwirtsch. Inst. Univ. Breslau, 1898, abst. in Cent. f. Bakt., II Abt., *5*, 1899, 678.) From tap water and soil. The position of this organism in relation to other *Schizomycetes* is very uncertain. It is regarded by Boltjes (Arch. f. Mikrobiol., 7, 1936, 188) as an organism which may be transitional between *Schizomycetes* and *Phycomycetes*. The cells possess structures which appear to be polar flagella; but with dark field illumination show an attached thread of ultramicroscopic size. Reproduction by cell division was not observed. Possibly this may be by budding from the attached thread. Associated with *Nitrobacter spp.* This is the type species of the genus *Hyphomicrobium* Stutzer and Hartleb.

Suborder III. Rhodobacteriineae Breed, Murray and Hitchens.*

(Family *Rhodobacteriaceae* Migula, Syst. d. Bakt., *2*, 1900, 1042; Breed, Murray and Hitchens, Bact. Rev., *8*, 1944, 257.)

Cells spherical, rod-, vibrio-, or spiral-shaped. Size of individual cells from less than 1 to over 20 microns. Motility, when exhibited, due to the presence of polar flagella. Gram-negative so far as known. No endospores formed. Red, purple, brown or green bacteria which contain bacteriochlorophyll or other chlorophyll-like green pigments, and usually also possess one or more carotenoid pigments. Capable of carrying out a photosynthetic metabolism which differs from that of green plants in that it does not proceed with the evolution of oxygen, and depends upon the presence of extraneous oxidizable compounds which are dehydrogenated with the simultaneous reduction of carbon dioxide. As oxidizable substrates a variety of simple substances can be used, such as sulfide, or other reduced sulfur compounds, molecular hydrogen, alcohols, fatty acids, hydroxy- and keto-acids, etc. All can be grown in strictly anaerobic cultures when illuminated. Those members which can grow in the presence of air can also be cultured in the dark under aerobic conditions. Color depends markedly on environmental conditions; small individuals appear colorless unless observed in masses. May contain sulfur globules. Described species have largely been found in fresh water habitats. Some species occur in marine habitats.

Key to the families of suborder **Rhodobacteriineae.**

I. Purple bacteria whose pigment system consists of bacteriochlorophyll and various carotenoids capable of carrying out a photosynthetic metabolism.
   A. Contain sulfur globules in the presence of hydrogen sulfide. The sulfur purple bacteria.
      Family I. *Thiorhodaceae*, p. 841.
   B. Do not contain sulfur globules even in the presence of hydrogen sulfide. All require organic growth factors. The non-sulfur purple and brown bacteria.
      Family II. *Athiorhodaceae*, p. 861.

II. Green sulfur bacteria containing a pigment system which has the characteristics of a chlorophyllous compound although it differs from the chlorophyll of green plants and from the bacteriochlorophyll of the purple bacteria.
      Family III. *Chlorobacteriaceae*, p. 869.

The organisms previously included in the order *Thiobacteriales* Buchanan do not constitute a taxonomic entity; they represent rather a physiological-ecological community. In this sense, however, a special treatment of this group as a unit has decided advantages from a determinative point of view.

When first proposed as a systematic assemblage, the order *Thiobacteria* Migula (Syst. d. Bakt., *2*, 1900, 1039) was intended to include the morphologically conspicuous organisms which, in their natural habitat, contain globules of sulfur as cell inclusions. Since Winogradsky (Beitr. z. Morph. u. Physiol. d. Bact., I, Schwefelbacterien, 1888) had elucidated the function of hydrogen sulfide and of sulfur in their metabolism, the characteristic inclusions appeared linked with a hitherto unrecognized type of physiology, *viz.* the oxidation of an inorganic substance instead of the decomposition of organic materials. From this oxidation the sulfur bacteria derive their energy for maintenance and growth.

* Completely revised by Prof. C. B. van Niel, Hopkins Marine Station, Pacific Grove, California, January, 1944.

Two groups of sulfur bacteria could be distinguished, one consisting of colorless, the other of red or purple organisms. The members of both groups presented an unusual morphology apart from the sulfur droplets; in all cases the individual cells were considerably larger than those of the common bacteria, while many species grew as distinctive colonial aggregates. Migula separated these sulfur bacteria into two families, *Beggiatoaceae* and *Rhodobacteriaceae*. Even at that time, however, some difficulties existed as to just what organisms should properly be considered as sulfur bacteria. Miyoshi (Jour. Coll. Sci., Imp. Univ., Tokyo, *10*, 1897, 143) had discovered a bacterium which forms stringers, incrusted with sulfur, in sulfur springs, but which does not store sulfur globules in its cells. Although physiologically this organism appeared to comply with Winogradsky's concept of a sulfur bacterium, the absence of the typical cell inclusions made Miyoshi decide it could not be considered as such. The problem was aggravated when Nathansohn, Beijerinck, and Jacobsen published their studies on small, colorless, *Pseudomonas*-like bacteria capable of oxidizing hydrogen sulfide, sulfur, and thiosulfate, and evidently dependent upon this oxidation process for their development. Morphologically these organisms have little in common with the *Beggiatoaceae*; they were designated by Beijerinck as species of *Thiobacillus* and have since been rightly considered as members of the order *Eubacteriales* (see p. 78). Nevertheless, these organisms are physiologically in no way different from the *Beggiatoaceae*, so that if physiology only is considered, a good case could be made out for their incorporation in the *Thiobacteriales*.

Furthermore, Molisch (Die Purpurbakterien, Jena, 1907, 95 pp.) described in some detail a number of bacterial species which, in view of their characteristic pigment system, appeared closely related to the *Rhodobacteriaceae*, but which develop only in organic media and are, therefore, not sulfur bacteria in the sense of Winogradsky or Migula. In stressing the importance of pigmentation Molisch combined the red sulfur bacteria and the newly discovered purple bacteria into an order *Rhodobacteria* with the two families *Thiorhodaceae* and *Athiorhodaceae*. It is this grouping that has been followed in the present edition of the MANUAL.

Only a very small number of typical sulfur bacteria have been studied in pure cultures. As a result the descriptions of genera and species rest mainly on observations made with collections from natural sources or crude cultures. Most investigators have implicitly accepted differences in cell size or in colonial appearance as a sufficient justification for establishing independent species. Evidently this procedure presupposes a considerable degree of constancy of such characteristics in the organisms in question. It is true that Winogradsky's investigations have provided a reasonable basis for this belief, but later studies with pure cultures of certain purple bacteria have established beyond a doubt that environmental conditions, such as composition of the medium and temperature, may exert a profound influence on the general morphology of these organisms. By this, it is not intended to infer that the previously proposed genera and species of sulfur bacteria should be abandoned. But it does follow that a cautious evaluation of the distinguishing features is necessary. In the absence of carefully conducted investigations on morphological constancy and variability of most of the previously recognized species of sulfur bacteria with pure cultures grown under a variety of external conditions, the best approach appears to be a tentative arrangement of these organisms based upon those characteristics which are readily ascertainable. Experience with this group over the past twenty years has shown that, while Winogradsky's fundamental work must remain the foundation of present taxonomic efforts, it is advisable to simplify the much more elaborate classification developed by Buchanan which was followed in previous editions of this MANUAL.

Certain genera of sulfur purple bacteria, created by Winogradsky, will very probably be consolidated when detailed information concerning the morphology of the organisms is available. Until such time it seems, however, best to retain most of them, even though the distinguishing characteristics are not always very clear. For the benefit of those who are familiar with previous methods of classification it will be indicated where deviations have been adopted.

The non-sulfur purple bacteria (*Athiorhodaceae* Molisch; *Rhodobacterioideae* Buchanan) have been subjected to a comparative morphological and physiological study comprising more than 150 strains, among which all previously proposed genera and species are represented (Van Niel, Bact. Rev., *8*, 1944, 1–118). It has been found that the characteristics upon which Molisch based the seven genera of this group are inadequate, and a new classification with only two distinguishable genera has been proposed. This system will be followed here.

Nadson (Bull. Jard. Imper. Bot., St. Petersburg, *12*, 1912, 64) described a new type of small, green bacteria, not containing sulfur globules in the presence of hydrogen sulfide, but excreting elementary sulfur. These appear incapable of oxidizing sulfur compounds other than sulfides. They are photosynthetic and are capable of growing in anaerobic culture when illuminated. The green pigment differs from the green plant chlorophylls and from the bacteriochlorophyll of the purple bacteria, but has the characteristics of a chlorophyllous compound. These are grouped in the family *Chlorobacteriaceae*.

FAMILY I. THIORHODACEAE MOLISCH.

(Molisch, Die Purpurbakterien, Jena, 1907, 27; Subfamily *Chromatioideae* Buchanan, Jour. Bact., *3*, 1918, 464; *Rhodo-Thiobacteria* Bavendamm, Die farblosen und roten Schwefelbacterien, Pflanzenforschung, Heft 2, 1924, 102; *Rhodothiobacteria* Bavendamm, Ergeb. Biol., *13*, 1936, 49.)

Unicellular organisms, often developing as cell aggregates or families of variable size and shape. Single cells have the form of spheres, ovoids, short rods, vibrios, spirals, long rods or, occasionally, chains. They occur in nature in environments containing sulfides and require light for their development; infra-red irradiation of a wave-length extending to about 900 millimicrons is effective. They produce a pigment system composed of green bacteriochlorophyll, and yellow and red carotenoids. As a result they appear as pale purple, brownish to deep red cell masses. Single cells, unless they are of considerable size, usually appear to be unpigmented. These are anaerobic or microaerophilic organisms, with a photosynthetic metabolism in which carbon dioxide is reduced with the aid of special hydrogen donors without the liberation of molecular oxygen. Where these organisms are found in nature, hydrogen sulfide acts as a hydrogen donor, and sulfur, the first intermediate oxidation product, accumulates as sulfur droplets in the cells. Probably all members of the group can utilize a number of organic substances other than hydrogen sulfide as hydrogen donors for photosynthesis. Thus they are potentially mixotrophic.

Characterization of the genera in this group has since Winogradsky's studies (Beiträge zur Morphologie und Physiologie der Schwefelbacterien, Leipzig, 1888) been based upon the mode of development of the cell aggregates. Pure culture studies (Bavendamm, Die farblosen und roten Bakterien, I. Schwefelbakterien, Pflanzenforschung, Heft 2, 1924, 74 pp.; van Niel, Arch. f. Mikrobiol., *3*, 1931, 1–112; Manten, Antonie van Leeuwenhoek, *8*, 1942, 164 pp.) have since shown that not only the sequence of events in the formation of the aggregates but also the appearance and form of the latter even including the size and shape of the component cells are influenced to a considerable extent by environmental conditions. This obviously casts doubt upon the usefulness of the previously used diagnostic criteria for genera and species. On the other hand, the scope of pure culture studies has not yet attained sufficient breadth to warrant the use of a different approach. As a provisional measure, Winogradsky's genera are therefore maintained. Even the larger taxonomic units must be regarded as being of tentative value only.

Key to the genera of the family **Thiorhodaceae.**

I. Cells usually combined into aggregates.
  A. Cells grouped as regular sarcina packets.
    Genus I. *Thiosarcina*, p. 842.
  B. Cells not in sarcina packets.
    1. Aggregates in the form of a flat sheet.
      a. Cells in regular arrangement, with tetrads as the common structural unit.
        Genus II. *Thiopedia*, p. 843.
      aa. Cells in irregular aggregates.
        Genus III. *Thiocapsa*, p. 844.

2. Aggregates in the form of three-dimensional masses.
   a. Cells distinctly rod-shaped, and arranged in a net-like structure.
      Genus IV. *Thiodictyon*, p. 845.
   aa. Cells not so arranged.
      b. Cells in a common capsule, individuals rather scattered and loosely grouped.
         Genus V. *Thiothece*, p. 846.
      bb. Cells in rather dense clumps.
         c. Aggregates embedded in conspicuous common slime capsule.
            d. Aggregates small, compact, often several of them enclosed together in a common capsule.
               Genus VI. *Thiocystis*, p. 846.
            dd. Aggregates large and solid, later break up into small clusters.
               Genus VII. *Lamprocystis*, p. 847.
         cc. Common capsule lacking or very transient.
            d. Aggregates as a whole exhibit amoeboid movements.
               Genus VIII. *Amoebobacter*, p. 848.
            dd. Aggregates devoid of amoeboid movements.
               Genus IX. *Thiopolycoccus*, p. 850.

II. Cells usually occurring singly.
   A. Cells clearly spiral-shaped.
      Genus X. *Thiospirillum*, p. 850.
   B. Cells not spiral-shaped.
      1. Cells irregular, often swollen, distorted, or composed of long, crooked and bent rods to filaments.
         Genus XI. *Rhabdomonas*, p. 853.
      2. Cells regular, spherical to short rods or bean-shaped.
         a. Cells spherical, as a rule non-motile, and each one surrounded by a rather wide capsule.
            Genus XII. *Rhodothece*, p. 855.
         aa. Cells ellipsoidal, ovoid, short rods or vibrios, actively motile.
            Genus XIII. *Chromatium*, p. 856.

Genus I. Thiosarcina *Winogradsky.*

(Winogradsky, Zur Morphologie und Physiologie der Bacterien, I. Schwefelbacterien, Leipzig, 1888, 104; *Rhodosarcina* Orla-Jensen, Cent. f. Bakt., II Abt., *22*, 1909, 344; *Rhodothiosarcina* Ellis, Sulphur Bacteria, London and New York, 1932, 163.) From Greek *theion*, sulfur and Latin *sarcina*, bundle, packet.

Individual cells spherical, forming regular cubical packets of sarcina-shape, resulting from consecutive division in three perpendicular planes. Packets commonly containing 8 to 64 cells. Motility infrequent. Non-spore-forming. Contain bacteriochlorophyll and carotenoid pigments, hence, pigmented purplish to red. Capable of carrying out a photosynthetic metabolism in the presence of hydrogen sulfide, cells then store sulfur globules. Anaerobic.

The type species is *Thiosarcina rosea* (Schroeter) Winogradsky.

1. **Thiosarcina rosea** (Schroeter) Winogradsky. (*Sarcina rosea* Schroeter, Kryptog. Flora von Schlesien, *3*, 1, 1886, 154; *Sarcina sulphurata* Winogradsky, Bot. Ztg., *45*, 1887, 576; Winogradsky, Zur Morphologie und Physiologie

der Schwefelbacterien, Leipzig, 1888, 104; *Rhodothiosarcina rosea* Ellis, Sulphur Bacteria, London and New York, 1932, 163.) From Latin *roseus*, rose-colored.

Cells spherical, 2 to 3 microns in diameter, occurring in packets containing 8 to 64 cells. Infrequent motility. Color ranging from purplish-rose to nearly black.

Anaerobic.

Habitat: Mud and stagnant bodies of water containing hydrogen sulfide and exposed to light; sulfur springs.

Distribution: Probably ubiquitous. One of the less frequent among the purple sulfur bacteria.

Illustration: Issatchenko, Recherches sur les microbes de l'océan glacial arctique, Petrograd, 1914, Plate II, fig. 5.

Genus II. Thiopedia *Winogradsky.*

(Zur Morphologie und Physiologie der Bacterien, I. Schwefelbacterien, Leipzig, 1888, 85.) From Greek *theion* sulfur and *pedion*, plane.

Individual cells spherical to short rod-shaped, the latter shortly before cell division. Arranged in flat sheets with typical tetrads as the structural units. These arise from divisions of the cells in two perpendicular directions. Cell aggregates of various sizes, ranging from single tetrads to large sheets composed of thousands of cells. Motility infrequent. Non-spore-forming. Contain bacteriochlorophyll and carotenoid pigments. Capable of photosynthesis in the presence of hydrogen sulfide, and then storing sulfur globules. Anaerobic.

The type species is *Thiopedia rosea* Winogradsky.

1. **Thiopedia rosea** Winogradsky. (*Erythroconis littoralis* Oerstedt, Naturhist. Tidskrift, *3*, 1840–1841, 555; *Merismopedia littoralis* Rabenhorst, Flora Europaea Algarum, Leipzig, *2*, 1865, 57; Winogradsky, Zur Morphologie und Physiologie der Schwefelbacterien, Leipzig, 1888, 85; *Pediococcus roseus* Trevisan, I generi e le specie delle Batteriacee, Milan, 1889, 28; *Lampropedia rosea* DeToni and Trevisan, in Saccardo, Sylloge Fungorum, *8*, 1889, 1049; *Planococcus roseus* Migula, in Engler and Prantl, Die natürlichen Pflanzenfamilien, *1*, 1a, 1895, 19.) From Latin *roseus*, rose-colored.

Size: 1 to 2 microns, often appearing as slightly elongated cocci regularly arranged in platelets. Color, pale red to nearly black, depending upon the amount of sulfur stored. Red color visible only with large cell masses, not in individuals.

According to Winogradsky, the cells are often embedded in a common slime capsule; the extensive studies of Utermöhl (Archiv f. Hydrobiol., Suppl. Vol. *5*, 1925, 251–276) make the regular occurrence of such capsules extremely doubtful. On the other hand, Utermöhl emphasizes as quite characteristic the common presence of a relatively large pseudovacuole, or aerosome, in the cells of this species encountered in plankton samples. Winogradsky does not mention this; nevertheless, it appears to be a regular and valuable distinguishing feature.

Anaerobic.

Habitat: Mud and stagnant bodies of fresh, brackish and salt water containing hydrogen sulfide and exposed to light; sulfur springs.

Distribution: Ubiquitous. Common, frequently giving rise to very extensive mass developments.

Illustrations: Warming, Videnskab. Meddel. naturhist. Forening, Kjöbenhavn, 1876, Plate VIII, fig. 2; Winogradsky, *loc. cit.*, Plate III, fig. 18; Pringsheim, Naturwissensch., *20*, 1932, 481, the last one a truly excellent photomicrograph.

Appendix: The following genus was formerly placed near *Thiopedia.* Winogradsky, Migula, E. F. Smith and others disregard this genus. A record is included here because of its historic interest.

Genus A. *Lampropedia* Schroeter.

(Schroeter, in Cohn, Kryptog. Flora v. Schlesien, *3*, 1, 1886, 151.) From Greek *lampros*, bright and *pedion*, plane.

Trevisan (I generi e le specie delle Batteriacee, 1889, 28) and DeToni and Trevisan (in Saccardo, Sylloge Fungorum, *8*, 1889, 1048) list as synonyms: *Erythroconis* Oersted, Naturhistorisk Tidsskrift, *2*, 1840, 555; in part, *Pediococcus* Lindner, Inaug. Diss., Berlin, 1887, 97; *Thiopedia* Winogradsky, Schwefelbacterien, Leipzig, 1888, 85.

Cells united into tetrads, forming flat, tubular masses, contain sulfur globules and bacteriochlorophyll and yellow and red carotenoids.

The type species is *Lampropedia hyalina* (Ehrenberg) Schroeter.

1. *Lampropedia hyalina* (Ehrenberg) Schroeter. (*Gonium hyalinum* Ehrenberg, Abhandl. d. Berl. Akad., 1830; *Merismopedia hyalina* Kützing, Species Algarum, 1849; *Sarcina hyalina* Winter, in Rabenhorst, Kryptogamen-Flora, 2 Aufl., *1*, 1884, 51; Schroeter, in Cohn, Kryptogram. Flora v. Schlesien, *3*, *1*, 1886, 151; *Pediococcus hyalinus* Trevisan, I generi e le specie delle Batteriacee, 1889, 28; *Micrococcus hyalinus* Migula, Syst. d. Bakt., *2*, 1900, 195.) From swamp water and decomposing materials from sugar refineries.

2. *Lampropedia reitenbachii* (Caspary) DeToni and Trevisan. (*Merismopedium reitenbachii* Caspary, Schriften d. physik. ökon. Gesellsch. zu Königsberg, *15*, 1874, 104; *Sarcina reitenbachii* Winter, in Rabenhorst, Kryptogamen-Flora, 2 Aufl., *1*, 1884, 50; *Pediococcus reichenbachii* (sic) Trevisan, I generi e le specie delle Batteriacee, 1889, 28; DeToni and Trevisan, in Saccardo, Sylloge Fungorum, *8*, 1889, 1048.) Found on rotting water-plants.

3. *Lampropedia violacea* (Breb.) DeToni and Trevisan. (*Agmenellum violaceum* Breb., quoted from DeToni and Trevisan, in Saccardo, Sylloge Fungorum, *8*, 1889, 1049; *Merismopedia violacea* Kützing, Species Algarum, 1849, 472; *Pediococcus violaceus* Trevisan, I generi e le specie delle Batteriacee, 1889, 28; DeToni and Trevisan, *loc. cit.*, 1048.) From stagnant water. Common.

4. *Lampropedia ochracea* (Mettenheimer) DeToni and Trevisan. (*Merismopedia ochracea* Mettenheimer, Abhandl. d. Senkemberg. naturforsch. Gesellsch. in Frankf., *2*, 1856–58, 41; DeToni and Trevisan, in Saccardo, Sylloge Fungorum, *8*, 1889, 1049.) From the yellowish slime from a well at Frankfurt.

Genus III. **Thiocapsa** *Winogradsky.*

(Schwefelbacterien, Leipzig, 1888, 84.) From Greek *theion*, sulfur and Latin *capsa*, container, capsule.

Cells spherical, occurring in families of irregularly arranged individuals held together in a common slime capsule. The aggregates are spread out flat on the substrate. Motility not observed. As the colony grows, the capsule bursts, and the cells are spread apart. General morphology and development thus appears similar to that in the genus *Aphanocapsa* among the blue-green algae. Contain bacteriochlorophyll and carotenoid pigments; capable of photosynthesis in the presence of hydrogen sulfide. Under such conditions sulfur is stored in the form of globules in

the cells. This genus is so much like *Thiothece* that it is doubtful whether a distinction can be maintained.

The type species is *Thiocapsa roseopersicina* Winogradsky.

Key to the species of genus **Thiocapsa.**

I. Individual cells about 3 microns in diameter.
1. *Thiocapsa roseopersicina.*

II. Individual cells about 1.5 microns in diameter.
2. *Thiocapsa floridana.*

1. **Thiocapsa roseopersicina** Winogradsky. (Schwefelbacterien, Leipzig, 1888, 84.) From Latin *roseus*, rose-colored and *persicum*, peach; M.L., peach-colored.

Cells: Spherical, 2.5 to 3 microns in diameter, occurring in families of irregularly arranged individuals held together in a common slime capsule. Motility not observed. Usually a distinct rose-red. Stored sulfur droplets may attain a considerable size.

Habitat: Mud and stagnant bodies of water containing hydrogen sulfide and exposed to light; sulfur springs.

Illustration: Winogradsky, *loc. cit.*, Plate IV, fig. 15.

2. **Thiocapsa floridana** Uphof. (Uphof, Arch. f. Hydrobiol., *18*, 1927, 84; *Thiocapsa minima* Issatchenko, Borodin Jubilee Volume, p. 6, 1929?.) From the locality, Florida, where the organism was first found.

Cells: Spherical. About 1.5 microns in diameter. In groups of irregular colonies, each surrounded by a common capsule, several colonies being stuck together. Motility not observed.

Source: Palm Springs, Florida and Lake Sakskoje, near Eupatoria, Crimea.

Habitat: Mud and stagnant water containing hydrogen sulfide and exposed to light; sulfur springs. Probably ubiquitous.

Illustration: Uphof, *loc. cit.*, 83, fig. VI.

Genus IV. **Thiodictyon** *Winogradsky.*

(Winogradsky, Schwefelbacterien, Leipzig, 1888, 80; *Rhododictyon* Orla-Jensen, Cent. f. Bakt., II Abt., *22*, 1909, 334.) From Greek *theion*, sulfur and *dictyon*, net.

Cells rod-shaped, frequently with pointed ends, somewhat resembling spindles. Form aggregates in which the cells become arranged end to end in a net-like structure, somewhat reminiscent of the shape of the green alga *Hydrodictyon*. The shape is not constant; cells may also form more compact masses. Sometimes groups of cells separate from the main aggregate by active movements. Common gelatinous capsule not observed. Contain bacteriochlorophyll and carotenoid pigments; cells usually very faintly colored. Capable of photosynthesis in the presence of hydrogen sulfide; the cells then store sulfur as small globules.

The type species is *Thiodictyon elegans* Winogradsky.

1. **Thiodictyon elegans** Winogradsky. (Winogradsky, Schwefelbacterien, Leipzig, 1888, 80; *Thiodictyon minus* Issatchenko, Recherches sur les microbes de l'océan glacial arctique, Petrograd, 1914, 251.) From Latin *elegans*, tasteful, elegant.

Rods: 1.5 to 1.7 by 2.5 to 5 microns; or longer just prior to cell division. Usually contain a large pseudovacuole (aerosome), leaving a rather thin protoplasmic sheath along the cell wall.

Sulfur droplets: Generally quite small, and deposited exclusively in the thin protoplasmic layer.

Issatchenko (Études microbiologiques des Lacs de Boue, Leningrad, 1927, 113–114) recognizes a forma *minus* and a forma *magna*, differentiated mainly by the size of the individual rods.

Habitat: Mud and stagnant water, containing hydrogen sulfide, and exposed to light; sulfur springs.

Illustrations: Winogradsky, *loc. cit.*, Plate III, fig. 13–17.

Genus V. **Thiothece** *Winogradsky.*

(Winogradsky, Schwefelbacterien, Leipzig, 1888, 82; *Thiosphaera* Miyoshi, Jour. Coll. Sci., Imp. Univ. Tokyo, Japan, *10*, 1897, 170.) From Greek *theion*, sulfur and *theke*, container.

Purple sulfur bacteria which, in their growth characteristics, resemble the blue-green alga *Aphanothece*. Cells spherical to relatively long cylindrical-ellipsoidal, embedded in a gelatinous capsule of considerable dimensions. Following cell division the daughter cells continue to secrete mucus which causes the individual bacteria to remain clearly separated by an appreciable distance; the common capsule thus appears only loosely filled. The cells may become actively motile and separate themselves from the colony. Such swarmers closely resemble the cells of certain species of *Chromatium*. Contain bacteriochlorophyll and carotenoid pigments. Capable of photosynthesis in the presence of hydrogen sulfide, producing elementary sulfur as an intermediate oxidation product which is stored as sulfur globules inside the cells.

The type species is *Thiothece gelatinosa* Winogradsky.

1. **Thiothece gelatinosa** Winogradsky. (Winogradsky, Schwefelbacterien, Leipzig, 1888, 82; *Thiosphaera gelatinosa* Miyoshi, Jour. Coll. Sci., Imp. Univ. Tokyo, Japan, *10*, 1897, 170; *Lamprocystis gelatinosa* Migula, Syst. d. Bakt., *2*, 1900, 1044; *Chromatium sphaeroides* Hama, Jour. Sci. Hiroshima Univ., Ser. B, Div. 2, Bot., *1*, 1933, 158.) From Latin *gelatio*, freezing, indicating solidification or clumping.

Cells: 4 to 6 by 4 to 7 microns, spherical to cylindrical. Color of individual cells, faint, often grayish-violet, or even dirty yellowish. Sulfur globules usually deposited in outermost layers of protoplasm, and generally small.

Habitat: Mud and stagnant water containing hydrogen sulfide and exposed to light; sulfur springs.

Illustrations: Winogradsky, *loc. cit.*, Pl. III, fig. 9–12; Miyoshi, *loc. cit.*, Pl. XIV, fig. 25.

Genus VI. **Thiocystis** *Winogradsky.*

(Schwefelbacterien, Leipzig, 1888, 60.) From Greek *theion*, sulfur and *kystis*, sac, bladder.

Purple sulfur bacteria which form compact colonies, many of which may be loosely embedded in a common gelatinous capsule. Individual cells spherical to ovoid, often diplococcus-shaped. Colonies may emerge as more or less large units from out of the common capsule and break up afterwards, sometimes into single swarmers; or the aggregates may split up inside the original capsule, and release small motile units or single swarmers. In pure cultures frequently developing as single cells and diplococci. Produce bacteriochlorophyll and carotenoid pigments, coloring the cell masses purplish to red. Capable of photosynthesis in the presence of hydrogen sulfide, whereby elementary sulfur is formed as an intermediate oxidation product which is deposited as droplets inside the cells.

The type species is *Thiocystis violacea* Winogradsky.

Key to the species of genus **Thiocystis.**

I. Individual cells more than 2 microns in width.
1. *Thiocystis violacea.*

II. Individual cells about 1 micron or less in width.
2. *Thiocystis rufa.*

1. **Thiocystis violacea** Winogradsky. (Winogradsky, Schwefelbacterien, Leipzig, 1888, 65; *Planosarcina violacea* Migula, in Engler and Prantl, Die natürl. Pflanzenfamilien, *1*, 1a, 1895, 20.) From Latin *violaceus*, violet-colored.

Cells: About 2.5 to 5.5 microns in diameter, spherical to ovoid. Swarmers actively motile by means of polar flagella.

Colonies: Small, inside a common capsule, containing not over 30 cells. Several such colonies form loosely arranged aggregates, most characteristically composed of about 10 to 20 colonies in a single capsule. The result is a nearly spherical zoogloea. In small colonies, the cells appear as rather distinct tetrads; in larger colonies, the cells become somewhat compressed and the tetrad-like arrangement may be lost.

In pure cultures, the species often fails to produce the characteristic capsules; the organisms then occur as actively motile single cells or diplococci, with little or no slime formation. No pseudocapsules are formed.

Habitat: Mud and stagnant water containing hydrogen sulfide and exposed to light; sulfur springs.

Illustrations: Zopf, Zur Morphologie der Spaltpflanzen, Leipzig, 1882, Pl. V, fig. 12; Winogradsky, *loc. cit.*, Pl. II, Fig. 1–7.

2. **Thiocystis rufa** Winogradsky. (Schwefelbacterien, Leipzig, 1888, 65.) From Latin *rufus*, red.

Cells: Less than 1 micron in diameter. Color red, usually darker than in the type species. When the cells are stuffed with sulfur globules, the aggregates appear almost black.

The common gelatinous capsule usually contains a far greater number of closely packed individual colonies than is the case in *Thiocystis violacea.*

Habitat: Mud and stagnant water containing hydrogen sulfide and exposed to light; sulfur springs.

Illustration: Winogradsky, *loc. cit.*, Pl. II, fig. 8.

Genus VII. **Lamprocystis** *Schroeter.*

(In part, *Clathrocystis* Cohn, Beitr. Biol. Pfl., *1*, Heft 3, 1875, 156; in part, *Cohnia* Winter, in Rabenhorst, Kryptogamen-Flora, 2 Aufl., 1884, 48; Schroeter, Die Pilze Schlesiens, in Cohn, Kryptogamen-Flora von Schlesien, *3*, 1, 1886, 151; *Cenomesia?* de Toni and Trevisan, in Saccardo, Sylloge Fungorum, *8*, 1889, 1039; *Lankasteron* Ellis, Sulphur Bacteria, London and New York, 1932, 135.) From Greek *lampros*, bright, shining, and *kystis*, sac or bladder.

Purple sulfur bacteria which form more or less large aggregates of cells enclosed in a common gelatinous capsule. Individual cells spherical to ovoid. Small aggregates closely resemble those of *Thiocystis*, even to the extent of the tetrad-like arrangement of cells in the small colonies. Behavior of the large aggregates during development appears to be different; the small individual cell groups or colonies do not emerge from the slime capsule until the initially relatively compact cell mass becomes broken up into smaller clusters, these eventually forming a somewhat net-

like structure. This behavior has been ascribed to a change in the mode of cell division which at first appears to take place in three perpendicular planes, and later presumably changes to a division in only two directions. Cells when free are motile by means of polar flagella. In pure culture also this type rarely, if ever, produces large aggregates with the development here mentioned as characteristic for the genus (Bavendamm, Die farblosen und roten Schwefelbakterien, Pflanzenforschung, Heft 2, 1924, 76). This, along with the other similarities, makes it doubtful whether future studies will result in the retention of the genera *Lamprocystis* and *Thiocystis* side by side. Produce bacteriochlorophyll and carotenoid pigments, coloring the cell masses purplish-pink to red. Capable of photosynthesis in the presence of hydrogen sulfide, storing elementary sulfur as globules inside the cells.

The type species is *Lamprocystis roseopersicina* (Kützing) Schroeter.

1. **Lamprocystis roseopersicina** (Kützing) Schroeter. (*Microloa rosca* Kützing, Linnaea, *8*, 1833, 371; *Cryptococcus roscus* Kützing, Phycologia generalis, Leipzig, 1843, 149; *Protococcus roseopersicinus* Kützing, Species Algarum, Leipzig, 1849, 196; *Palmella persicina* Cohn, Leonhard's Jarhb. f. Mineralog., 1864, 606; *Pleurococcus roseo-persicinus* Rabenhorst, Flora Eur. Algarum, Leipzig, *3*, 1868, 28; *Bacterium rubescens* Lankester, Quart. Rev. Micro. Sci., *13*, 1873, 408; not *Bacterium rubescens* Chester, Ann. Rept. Del. Col. Agr. Exp. Sta., *9*, 1897, 115; *Clathrocystis roseopersicina* Cohn, Beitr. Biol. Pfl., *1*, Heft 3, 1875, 157; *Cohnia roseo-persicina* Winter, in Rabenhorst, Kryptogamen Flora, 2 Aufl., *1*, 1884, 48; Schroeter, in Cohn, Kryptogamen-Flora von Schlesien, *3*, 1, 1886, 151; *Planosarcina roseo-persicina* Migula, in Engler and Prantl, Die natürlichen Pflanzenfam., *1*, 1a, 1895, 20; *Lankasteron rubescens* Ellis, Sulphur Bacteria, London and New York, 1932, 135.) From Latin *roseus*, rose-colored and *persicum*, peach; M.L., peach-colored.

In all probability, *Thioderma rubrum* Miyoshi (Jour. Coll. Sci., Imp. Univ. Tokyo, Japan, *10*, 1897, 170) is identical with this species.

Cells: Spherical to ovoid, 2 to 2.5 microns in diameter, up to 5 microns long before cell division. Motile. Polar flagellate.

Winogradsky (*loc. cit.*) reports that the cells frequently contain pseudovacuoles.

Habitat: Mud and stagnant water containing hydrogen sulfide and exposed to light; sulfur springs.

Illustrations: Warming, Videnskab. Meddel. naturhistor. Foren., Kjöbenhavn, 1876, Pl. VIII, fig. 3 g; Zopf, Z. Morphol. d. Spaltpflanzen, Leipzig, 1882, Pl. V, fig. 8, 13; Winogradsky, Schwefelbacterien, Leipzig, 1888, Pl. II, fig. 9–15; Bavendamm, Die farblosen und roten Schwefelbakterien, Jena, 1924, Pl. II, fig. 3.

Genus VIII. Amoebobacter *Winogradsky.*

(Winogradsky, Schwefelbacterien, Leipzig, 1888, 71; *Amoebomonas* Orla-Jensen, Cent. f. Bakt., II Abt., *22*, 1909, 334.) From *amoeba*, one of the protozoa characterized by a constantly changing shape, and Greek *baktron*, rod.

Purple sulfur bacteria, usually occurring in aggregates composed of many individuals without a characteristic common capsule. Slime formation can, nevertheless, be observed with very small colonies. With growth of the individual cells, the capsule bursts and the cell mass slowly moves out while the bacteria remain united. The colonies change their shape during growth and in response to environmental influences; the individual cells appear motile and cause the movements of the entire

colony. Winogradsky ascribes the coherence of the cell masses to the existence of interconnecting protoplasmic filaments between cells, but these have never been observed, and their occurrence is extremely doubtful. It is much more probable that the bacteria are held together by mucus, though not so much of the latter is produced as to form a clearly discernible capsule.

Produce bacteriochlorophyll and carotenoid pigments. Capable of photosynthesis in the presence of hydrogen sulfide, and then store sulfur as droplets inside the cells.

The type species is *Amoebobacter roseus* Winogradsky.

Since the characterization of the genera *Amoebobacter*, *Lamprocystis*, *Thiocystis*, *Thiocapsa* and *Thiothece* is based upon the arrangement of individual bacteria in a common capsule, which, from Winogradsky's descriptions of *Amoebobacter* and from pure culture studies with *Thiocystis* and *Lamprocystis*, has been shown to vary considerably, depending upon developmental stages and environmental conditions, it is quite possible that future investigations will show the desirability of restricting the number of genera.

Key to the species of genus **Amoebobacter.**

I. Cells spherical to ovoid, about 2.5 to 3.5 microns in diameter and up to 6 microns in length prior to cell division.
   1. *Amoebobacter roseus.*

II. Cells distinctly rod-shaped, about 1.5 to 2 microns in width by 2 to 4 microns in length.
   2. *Amoebobacter bacillosus.*

III. Cells spherical, quite small, about 0.5 to 1 micron in diameter.
   3. *Amoebobacter granula.*

1. **Amoebobacter roseus** Winogradsky. (Schwefelbacterien, Leipzig, 1888, 77.) From Latin *roseus*, rose.

Cells spherical to ovoid, 2.5 to 3.5 microns in width and up to 6 microns in length. Motile. Often contain pseudovacuoles. Cell-aggregates often form transitory hollow spheres or sacks, with the bacteria occupying the periphery as a shallow layer. These are reminiscent of stages in the development of *Lamprocystis*.

Habitat: Mud and stagnant water containing hydrogen sulfide and exposed to light; sulfur springs.

Illustrations: Winogradsky, *loc. cit.*, Pl. III, fig. 1–6.

2. **Amoebobacter bacillosus** Winogradsky. (Winogradsky, Schwefelbacterien, Leipzig, 1888, 78; *Thioderma roseum* Miyoshi, Jour. Coll. Sci., Imp. Univ. Tokyo, Japan, *10*, 1897, 158.) From Latin *bacillus*, resembling a rod.

Cells rod-shaped, about 1.5 to 2 microns by 2 to 4 microns. Cells contain pseudovacuoles (aerosomes). Sulfur globules deposited exclusively in peripheral protoplasmic layer, usually quite small.

Habitat: Mud and stagnant water, containing hydrogen sulfide and exposed to light; sulfur springs.

Illustrations: Zopf, Z. Morphol. d. Spaltpfl., Leipzig, 1882, Pl. V, fig. 26–27; Winogradsky, *loc. cit.*, Pl. III, fig. 7.

Miyoshi's incomplete description of *Thioderma roseum* (*loc. cit.*), type species of genus *Thioderma*, is sufficient to make practically certain that it is identical with *Amoebobacter bacillosus*. The description of *Thiodictyon elegans* Winogradsky (*loc. cit.*) suggests that it cannot be distinguished from this species.

3. **Amoebobacter granula** Winogradsky. (Schwefelbacterien, Leipzig, 1888, 78.) From Latin *granulus*, a granule.

Cells: Spherical, small, about 0.5 to 1 micron in diameter. Faint pigmentation; the sulfur inclusions give the cell masses a black appearance. Aggregates are apt to consist of closely-knit masses which are difficult to separate.

When sulfur is stored, a single droplet usually fills most of the cell. Because of the high refractive index of this globule, it becomes difficult if not impossible to make accurate observations of the cell shape.

Habitat: Mud and stagnant water containing hydrogen sulfide and exposed to light; sulfur springs.

Illustration: Winogradsky, *loc. cit.*, Pl. III, fig. 8.

Genus IX. **Thiopolycoccus** *Winogradsky.*

(Winogradsky, Schwefelbacterien, Leipzig, 1888, 79; *Rhodopolycoccus* Orla-Jensen, Cent. f. Bakt., II Abt., *22*, 1909, 334.) From Greek *theion*, sulfur; *polys*, many; and *kokkos*, granule or small cell.

Purple sulfur bacteria which form dense aggregates of rather solid construction and irregular shape. The colonies appear, in contrast with *Amoebobacter*, non-motile and do not tend to form hollow zoogloeal structures by which they are differentiated from *Lamprocystis*. Cell masses held together by mucus which does not, however, appear as a regular capsule. Large clumps may fissure with the formation of irregular shreds and lobes which continue to break up into smaller groups of cells. Individual bacteria spherical, motility not observed. Contain bacteriochlorophyll and carotenoid pigments, so that the aggregates, in accord with the dense packing with individual cells, appear distinctly red. Capable of photosynthesis in the presence of hydrogen sulfide, when the cells store elementary sulfur as droplets inside the cells.

The type species is *Thiopolycoccus ruber* Winogradsky.

1. **Thiopolycoccus ruber** Winogradsky. (Winogradsky, Schwefelbacterien, Leipzig, 1888, 79; *Micrococcus ruber* Migula, in Engler and Prantl, Die natürlichen Pflanzenfamilien, *1*, 1a, 1895, 18.) From Latin *ruber*, red.

Cells: Spherical, about 1.2 microns in diameter. No motility observed.

Habitat: Mud and stagnant water containing hydrogen sulfide and exposed to light; sulfur springs.

Illustrations: Winogradsky, *loc. cit.*, Pl. IV, fig. 16–18; Issatchenko, Recherches sur les microbes de l'océan glacial arctique, Petrograd, 1914, Pl. II, fig. 7.

Genus X. **Thiospirillum** *Winogradsky.*

(*Ophidomonas* Ehrenberg, Die Infusionstierchen, Leipzig, 1838, 43; Winogradsky, Schwefelbacterien, Leipzig, 1888, 104; *Thiorhodospirillum* Fuhrmann, Vorlesungen ü. techn. Mykologie, Jena, 1913, 325; *Rhodothiospirillum* Bavendamm, Schwefelbakterien, Jena, 1924, 115.) From Greek *theion*, sulfur, and diminutive of *spira*, screw.

Purple sulfur bacteria, occurring singly, as spirally wound cells, motile by means of polar flagella. Contain bacteriochlorophyll and carotenoid pigments, coloring the cells brownish- to purplish-red. Capable of photosynthesis in the presence of hydrogen sulfide, during which they produce and store, as an intermediate oxidation product, elementary sulfur in the form of droplets inside the cells.

The differentiation of species in this group has been based exclusively on observa-

tions with material from natural collections and from laboratory mass cultures. The criteria used are the size and shape of the spirals, and the color of the organisms. Not a single representative has so far been obtained and studied in pure culture, so that no information is available concerning the constancy or variability of these characteristics. It is, however, likely that such properties may be greatly influenced by environmental factors. Hence, the following key and descriptions of species are apt to be modified when more extensive studies have been made. The published descriptions of some species make it seem probable that they should not even be incorporated in *Thiospirillum*.

The type species is *Thiospirillum jenense* (Ehrenberg) Winogradsky.

Key to the species of genus **Thiospirillum.**

I. Width of cells 2.5 microns or more.
   1. Color of cells, especially in masses, yellowish-brown to orange-brown.
      1. *Thiospirillum jenense.*
   2. Color of cells deep red or violet.
      a. Cells long, typical spirals; clearly red.
         2. *Thiospirillum sanguineum.*
      aa. Cells short, slightly curved, vibrio-shaped; color purple to violet-red.
         3. *Thiospirillum violaceum.*

II. Width of cells less than 2.5 microns.
   1. Width of cells 1.5 to 2.5 microns.
      4. *Thiospirillum rosenbergii.*
   2. Width of cells about 1 micron.
      5. *Thiospirillum rufum.*

1. **Thiospirillum jenense** (Ehrenberg) Winogradsky. (*Ophidomonas jenensis* Ehrenberg, Die Infusionstierchen, Leipzig, 1838, 44; *Spirillum jenense* Trevisan, Batter. ital., 1879, 26; Winogradsky, Schwefelbacterien, Leipzig, 1888, 104; *Rhodothiospirillum jenense* Ellis, Sulphur Bacteria, London and New York, 1932, 161; *Thiospirillum crassum* Hama, Jour. Sci. Hiroshima Univ., Ser. B, Div. 2, Bot., *1*, 1933, 157.) Named for the city of Jena, Germany, where Ehrenberg discovered this organism.

Cells: Cylindrical, sometimes pointed at ends, 2.5 to 4 microns long, coiled as spirals. Generally 30 to 40 microns in length but may be as long as 100 microns. Shape of individual coils varies, complete turns measuring about 15 to 40 microns in length, and from ½ to 1/10 of the width in height. Polar flagellate. Tufted at both ends. Olive-brown, sepia-brown and reddish-brown.

This coloring appears to be the only recognizable difference from *Thiospirillum sanguineum*. *Thiospirillum crassum* Hama (*loc. cit.*) reported to be 3.7 to 4 by 12 to 40 microns and yellowish-brown in color, thus becomes indistinguishable from *Thiospirillum jenense*; the 80 microns long *Thiospirillum jenense* forma *maxima* Szafer (Bull. Acad. Sci. Cracovie, Sér. B, 1910, 162) does not at present justify recognition as a special taxonomic entity.

It is even doubtful whether the observed color difference between *Thiospirillum jenense* and *Thiospirillum sanguineum* constitutes a valid criterion for their maintenance as two distinct species (Buder, Jahrb. wiss. Bot., *56*, 1915, 534; Bavendamm, Die farblosen und roten Schwefelbakterien, Pflanzenforschung, Heft 2, 1924, 131).

Habitat: Mud and stagnant water containing hydrogen sulfide and exposed to light; more rarely in sulfur springs.

Illustrations: Zettnow, Ztschr. f. Hyg., *24*, 1897, Pl. II, fig. 49-52; Buder, *loc. cit.*, fig. 1; Szafer, *loc. cit.*, Pl. IV, fig. 4; Hama, *loc. cit.*, Pl. 18, fig. 1, 8a; Pl. 19, fig. 1.

2. **Thiospirillum sanguineum** (Ehrenberg) Winogradsky. (*Ophidomonas sanguinea* Ehrenberg, Verhandl. Akad. Wiss. Berlin, 1840, 201; *Spirillum sanguineum* Cohn, Beitr. Biol. Pfl., *1*, Heft 3, 1875, 169; Winogradsky, Schwefelbacterien, Leipzig, 1888, 104.) From Latin *sanguineus*, blood-colored, red.

Cells: Cylindrical, sometimes attenuated at ends, spirally coiled; 2.5 to 4.0 microns in width, commonly about 40 microns long with a range of from 10 to 100 microns. Size and shape of coils variable, complete turns measuring from 15 to 40 microns in length and from ⅓ to 1/10 of the length in width. Polar flagellate, usually tufted at both ends. Individual cells rose-red with a grayish hue, groups of cells deep red. Sulfur droplets numerous under appropriate conditions.

Habitat: Mud and stagnant water containing hydrogen sulfide and exposed to light; rarely in sulfur springs.

Illustrations: Cohn, *loc. cit.*, Pl. VI, fig. 15; Warming, Vidensk. Meddel, naturhist. Foren., Kjöbenhavn, 1876, Pl. VII, fig. 8; Buder, Jahrb. wiss. Bot., *56*, 1915, 534, fig. 2.

3. **Thiospirillum violaceum** (Warming) Winogradsky. (*Spirillum violaceum* Warming, Vidensk. Meddel. naturhist. Foren., Kjöbenhavn, 1876, 395; Winogradsky, Schwefelbacterien, Leipzig, 1888, 104.) From Latin *violaceus*, violet-colored.

Cells: Short and fat, 3 to 4 by 8 to 10 microns, ends smoothly rounded. Slightly curved, bean- or vibrio-shaped. Only rarely are they twisted suggesting a spirillum. Polarly flagellated.

The shape of cell seems to fit the genus *Chromatium* rather than *Thiospirillum* and Warming (*loc. cit.*) emphasizes the resemblance to *Chromatium okenii*.

Color bluish-violet; this color may be related to a scarcity of sulfur droplets in the cells.

Habitat: Mud and stagnant water.

Illustration: Warming, *loc. cit.*, Pl. VII, fig. 3.

4. **Thiospirillum rosenbergii** (Warming) Winogradsky. (*Spirillum rosenbergii* Warming, Vidensk. Meddel. naturhist. Foren., Kjöbenhavn, 1876, 346; Winogradsky, Schwefelbacterien, Leipzig, 1888, 104.) Named for the Danish algologist, Rosenberg.

Cells: 1.5 to 2.5 by 4 to 12 microns; coiled, with turns of about 6 to 7.5 microns in length and variable width up to 3 or 4 microns. Color very dark, due to numerous sulfur globules. Color of protoplasm not recorded.

Habitat: Mud and stagnant water containing hydrogen sulfide and exposed to light.

Distribution: Probably ubiquitous, but less frequently recorded as the organism is not as spectacular as the large *Thiospirillum jenense* and *Thiospirillum sanguineum*.

Illustration: Warming, *loc. cit.*, Pl. X, fig. 12.

5. **Thiospirillum rufum** (Perty) Migula. (*Spirillum rufum* Perty, Bern, 1852, 179; Migula, Syst. d. Bakt. *2*, 1900, 1050.) From Latin *rufus*, red, reddish.

General characteristics presumably those of the genus, although it does not appear either from Perty's description, or from those of Migula (*loc. cit.*), Bavendamm (Die farblosen und roten Schwefelbakterien Jena, 1924, 132) and Huber-Pestalozzi (Die Binnengewässer, *16*, Heft 1, Das Phytoplankton des Süsswassers, Stuttgart, 1938, 304) that the cells ever contain sulfur globules. Only the red color is emphasized. Consequently, it is quite possible that this

organism belongs in the genus *Rhodospirillum*.

Cells: 1.0 by 8 to 18 microns; coiled to occupy $1\frac{1}{2}$ to 4 turns, the latter commonly 4 microns wide by 4 microns long. These dimensions agree with those of *Rhodospirillum rubrum* (Esmarch) Molisch and the identity of the two organisms is probable.

Habitat: Found in red slime spots on the side of a well. Mud and stagnant bodies of water.

Illustration: Migula, Syst. d. Bakt., *1*, 1897, Pl. III, fig. 7.

Appendix: Three species have been placed in the genus *Thiospirillum* without convincing evidence that they conform to the generic diagnosis.

Thiospirillum agilis Kolkwitz. (Kolkwitz, Kryptogamenflora d. Mark Brandenburg, *5*, Pilze, 1909, 162; *Thiospira agilis* Bavendamm, Die farblosen und roten Schwefelbakterien, Pflanzenforschung, Heft 2, 1924, 116.) This is not known to have been a purple bacterium and hence may represent a member of the genus *Thiospira*.

Thiospirillum agilis var. *polonica* Strzeszewski. (Bull. Acad. Sci., Cracovie, Sér. B, 1913, 322.) This also may belong in the genus *Thiospira*.

Thiospirillum pistiense Czurda. (Cent. f. Bakt., II Abt., *92*, 1935, 409.) Not described as pigmented and does not contain sulfur globules. Reported to be a probable agent in the production of hydrogen sulfide from sulfates or sulfur. It may therefore be the spirillar form of *Vibrio desulfuricans* Beijerinck or, being thermophilic, of *Vibrio thermodesulfuricans* Elion.

Thiospirillum winogradskii Omeliansky. (Cent. f. Bakt., II Abt., *14*, 1905, 764.) This is colorless and is included in *Thiospira*.

Genus XI. Rhabdomonas *Cohn*

(Cohn, Beitr. Biol. Pfl., *1*, Heft 3, 1875, 167; *Mantegazzaea* Trevisan, R. Inst. Lombardo de Sci. e Lett., IV, Ser. 2, *12*, 1879, 137; *Rhabdochromatium* Winogradsky, Schwefelbacterien, Leipzig, 1888, 100; in part, *Rhodocapsa* Molisch, Die Purpurbakterien, Jena, 1907, 17.) From Greek *rhabdos*, a rod, and *monas*, a unit (cell).

Purple sulfur bacteria, as a rule occurring singly, in the form of rather irregular, long rods to filaments, exhibiting more or less pronounced swellings, or club and spindle shapes. Filamentous structures sometimes with constrictions giving the filament the appearance of a string of beads. These may be surrounded by a relatively inconspicuous slime capsule which can be rendered visible by India ink. The less distorted cell types are frequently motile, flagella polar. Produce bacteriochlorophyll and carotenoid pigments, coloring the cells pinkish- to purplish-red. Capable of photosynthesis in the presence of hydrogen sulfide and then storing sulfur globules as an intermediate oxidation product inside the cells.

The status of this genus is doubtful. Winogradsky (*loc. cit.*) recognized the similarity of its members to species of *Chromatium* and the occurrence of many intermediate forms which make a sharp distinction between the two genera impossible. He preferred the designation of *Rhabdochromatium* as a sub-genus. Warming (Videnskab. Meddel. naturhist. Foren., Kjöbenhavn, 1876, 320 ff.), Nadson (Bull. Jard. Impér. Bot. St. Pétersb., *3*, 1903, 116), van Niel (Arch. f. Mikrobiol., *3*, 1931, 61), and Ellis (Sulphur Bacteria, London and New York, 1932, 151) considered the species of *Rhabdochromatium* as abnormal growth forms (involution forms) of corresponding species of *Chromatium*, while Lauterborn (Verhandl. naturhistor.-medizin. Vereins, Heidelberg, N.F., *13*, 1915, 424), Buder (Jahrb. wiss. Bot., *58* 1919, 534) and Baven-

damm (Die farblosen und roten Schwefelbakterien, Pflanzenforschung, Heft 2, 1924, 129) favor generic rank.

The type species is *Rhabdomonas roseus* Cohn.

Key to the species of genus **Rhabdomonas.**

I. Cells not containing calcium carbonate inclusions in addition to sulfur globules.
 a. Cells more than 3 microns in width.
  1. *Rhabdomonas rosea.*
 aa. Cells less than 3 microns in width.
  2. *Rhabdomonas gracilis.*

II. Cells containing calcium carbonate inclusions in addition to sulfur globules.
  3. *Rhabdomonas linsbaueri.*

1. **Rhabdomonas rosea** Cohn. (Cohn, Beitr. Biol. Pfl., **1**, Heft 3, 1875, 167; *Beggiatoa roseo-persicina* Zopf, Z. Morphol. d. Spaltpflanzen, Leipzig, 1882, 30; *Rhabdochromatium roseum* Winogradsky, Schwefelbacterien, Leipzig, 1888, 100; *Rhabdochromatium fusiforme* Winogradsky, *ibid.*, 102; *Pseudomonas rosea* Migula, in Engler and Prantl, Die natürlichen Pflanzenfam., *1*, 1a, 1895, 30.) From Latin *roseus*, rose-colored.

Cells: Uneven in width and length, often swollen to spindle-shaped, sometimes tending towards filamentous growth. The greatest width of a spindle-shaped or fusiform cell may be close to 10 microns; in the more filamentous structures it is usually around 5 microns. The length varies between 10 and 30 microns for single cells; filamentous forms, frequently showing bulges and constrictions suggestive of compound structures in which cell division has been incomplete, may attain considerably greater lengths, up to 100 microns. The ends of spindle-shaped cells often taper to very fine points or attenuated fibers; also filaments are generally thinner toward the extremities. Single individuals and short filaments are motile by means of polar flagella, long filaments rarely motile. The ends of a filament may become pinched off and swim away.

Color rose-red; cells are usually filled with sulfur globules.

There is no good reason for maintaining *Rhabdomonas fusiformis* (*Rhabdochromatium fusiforme* Winogradsky) as a separate species; the variations in size and shape bring this form well within the range of *Rhabdomonas rosea*. Present indications strongly suggest that the latter species should be regarded as a peculiar developmental form of *Chromatium okenii*.

Habitat: Mud and stagnant water containing hydrogen sulfide and exposed to light; sulfur springs.

Illustrations: Cohn, *loc. cit.*, Pl. VI, fig. 14; Warming, Vidensk. Meddel. naturhistor. Foren., Kjöbenhavn, 1876, Pl. VII, fig. 1c-e; Zopf, *loc. cit.*, Pl. V, fig. 2b; Winogradsky, *loc. cit.*, Pl. IV, fig. 9-11, 13-14.

2. **Rhabdomonas gracilis** (Warming) Migula. (*Monas gracilis* Warming, Vidensk. Meddel. naturhist. Foren., Kjöbenhavn, 1876, 331; *Rhabdochromatium minus* Winogradsky, Schwefelbacterien, Leipzig, 1888, 102; *Rhabdochromatium gracile* Migula, Syst. d. Bakt., *2*, 1900, 1049; *Rhodocapsa suspensa* Molisch, Die Purpurbakterien, Jena, 1907, 17; *Rhabdomonas minor* Bergey et al., Manual, 3rd ed., 1930, 532.) From Latin *gracilis*, slender.

Cells: Much smaller than those of *Rhabdomonas rosea*, and with less tendency to form fusiform cells. Usually filamentous, more or less cylindrical, often with constrictions, but found up

to 60 microns in length. Shorter filaments motile. Polar flagellate. Slime formation may occur under special conditions. Rose-red. Sulfur globules. Probably an abnormal growth form of *Chromatium virosum*.

Habitat: Mud and stagnant water containing hydrogen sulfide and exposed to light; sulfur springs.

Illustrations: Warming, *loc. cit.*, Pl. VII, fig. 5; Winogradsky, *loc. cit.*, Pl. IV, fig. 12; Molisch, *loc. cit.*, Pl. II, fig. 11–12.

3. **Rhabdomonas linsbaueri** (Gicklhorn) *comb. nov.* (*Rhabdochromatium linsbaueri* Girklhorn, Ber. d. deut. bot. Ges., *39*, 1921, 312.) Named for the botanist, K. Linsbauer.

Cells: Resemble *Rhabdomonas rosea*, irregular, rod-shaped, 3 to 5 microns wide, up to 30 microns in length.

The characteristic feature of the species, and the chief means of differentiation, is the occurrence of calcium carbonate inclusions in addition to the sulfur globules in the cells. Whether this is strictly an environmentally conditioned characteristic, due to the photosynthetic development of the bacteria in a medium rich in calcium ions, so that calcium carbonate is precipitated as the alkalinity increases, has not yet been established, but seems possible. In that case the identity of this species with *Rhabdomonas rosea* would become evident.

Source: From a pond near Graz, Austria.

Habitat: Fresh water.

Genus XII. Rhodothece *Molisch.*

(Die Purpurbakterien, Jena, 1907, 19.) From Greek *rhodon*, rose and *theke*, container, capsule.

Purple sulfur bacteria, occurring singly, not aggregated in families. Cells spherical, each surrounded by a rather wide capsule which is, however, rarely visible without special staining. Motility not observed. Contain bacteriochlorophyll and carotenoid pigments, coloring the cells reddish. Capable of photosynthesis in the presence of hydrogen sulfide; the cells then store sulfur globules, arising as an intermediate oxidation product of the sulfide.

In view of the experiences of Bavendamm and others that a number of representatives of the purple sulfur bacteria, characterized by typical colonial aggregates when found in nature, may develop as single cells in pure culture, it is quite conceivable that the genus *Rhodothece* is synonymous with some other genus, e.g., *Lamprocystis*, and that the two genera represent different growth forms induced by environmental conditions.

The type species is *Rhodothece pendens* Molisch.

1. **Rhodothece pendens** Molisch. (Die Purpurbakterien, Jena, 1907, 19.) From Latin *pendeo*, to be suspended.

Cells: Spherical, frequently occurring as diplococci, occasionally as very short chains or clumps of 3 to 5 individuals. 1.8 to 2.5 microns in diameter. Produce rather abundant slime. Cells embedded in individual capsules which are rarely visible without staining (India ink). Characteristic is the regular occurrence of pseudovacuoles (aerosomes) which are supposed to keep the cells suspended in liquid media. Refractive phenomena due to the pseudovacuoles and to the sulfur globules distort the cell shape under ordinary illumination so that bacteria appear as polygons rather than round cells. Usually 2 aerosomes and 2 sulfur globules per cell. Color not observable in individual bacteria. Cell groups are rose-red. Motility not observed.

Habitat: Mud and stagnant water con-

taining hydrogen sulfide and exposed to light. Not reported from sulfur springs.

Illustrations: Molisch, Die Purpurbakterien, Jena, 1907, Pl. II, fig. 13-14.

Genus XIII. **Chromatium** *Perty.*

(Perty, Zur Kenntniss kleinster Lebensformen, Bern, 1852, 174; *Rhodomonas* Orla-Jensen, Cent. f. Bakt., II Abt., *22*, 1909, 334.) From Greek *chroma*, color.

Cells occur singly, more or less ovoid, bean- or vibrio-shaped, or short rods. The last-mentioned are often thick-cylindrical with rounded ends. Motile by means of polar flagella. Contain bacteriochlorophyll and carotenoid pigments, coloring the cells various shades of red. Capable of photosynthesis in the presence of hydrogen sulfide and storing elementary sulfur as an incomplete oxidation product in the form of globules inside the cells.

At present, the genus contains 11 described species and one variety. In addition, two more purple sulfur bacteria, *Pseudomonas molischii* Bersa (Planta, *2*, 1926, 375) and *Thiospirillum coccineum* Hama (Jour. Sci. Hiroshima Univ., Ser. B, Div. 2, Bot., *1*, 1933, 158), have been incorporated here as species of *Chromatium* because the descriptions and illustrations furnished by the original authors leave no doubt as to their taxonomic affiliations.

Differentiation of species has, in the past, been based almost entirely upon size and shape of individual cells, often with complete disregard for the variability of these criteria. The unsatisfactory and arbitrary nature of such a classification has occasionally been pointed out, and with much justification. Winogradsky (Schwefelbacterien, Leipzig, 1888, 98) mentions the many transitional stages that can be observed between *Chromatium okenii* and *Chromatium weissei*; Strzeszewski (Bullet. Acad. Sci., Cracovie, Sér. B, 1913, 321) holds that it is impossible to distinguish, on the basis of sizes or otherwise, between *Chromatium weissei* and *Chromatium minus*. Such contentions, derived from observations on material from natural collections or crude cultures, have been greatly strengthened by studies with pure cultures of species of *Chromatium*. Thus van Niel (Arch. f. Mikrobiol., *3*, 1931, 59) reported variations in width from 1 to 4 microns, and in length from 2 to 10 microns or even up to 50 microns; Manten (Antonie van Leeuwenhoek, *8*, 1942, 164 ff.) found size differences of 1 to 14 microns with a pure culture of an organism that he identified as *Chromatium okenii*. Often the differences in size of a pure culture can be related to special environmental conditions. On account of such results a designation of species on the basis of size relations alone is manifestly unsatisfactory. Moreover, the available data do not suggest that differences in shape, color or arrangement of sulfur globules can be used more effectively. Lack of adequate experimental results with a sufficiently large number and variety of pure cultures prevents a more rational classification at present.

The previously proposed species have been listed below with their respective characteristics and arranged as far as possible in the order of decreasing width.

Two *Chromatium* species have been described as containing inclusions of calcium carbonate in addition to sulfur globules. As in the case of *Rhabdomonas linsbaueri*, it is not known whether this feature may be a direct consequence of the calcium ion content and pH of the environment, and thus fail to have taxonomic significance.

The type species is *Chromatium okenii* Perty.

1. **Chromatium gobii** Issatchenko. (Recherches sur les microbes de l'océan glacial arctique, Petrograd, 1914, 253.)

Named for Prof. X. Gobi.

Cells: 10 microns by 20 to 25 microns.

Source: From sea water of Arctic Ocean.

Habitat: Presumably ubiquitous in the colder portions of the Ocean at least.

Illustration: Issatchenko, *loc. cit.*, Pl. II, fig. 12.

2. **Chromatium warmingii** (Cohn) Migula. (*Monas warmingii* Cohn, Beitr. Biol. Pfl., *1*, Heft 3, 1875, 167; Migula, Syst. d. Bakt., *2*, 1900, 1048.) Named for the Danish botanist, Eugene Warming.

Cells: 8 by 15 to 20 microns, also smaller (Cohn).

Illustration: Cohn, *loc. cit.*, Pl. VI, fig. 11.

2b. *Chromatium warmingii* forma *minus* Bavendamm. (Die farblosen und roten Schwefelbakterien, Pflanzenforschung, Heft 2, 1924, 127.) Named for the Danish botanist, Eugene Warming.

Cells: 4 by 6 to 10 microns.

Illustrations: Bavendamm, *loc. cit.*, 91, fig. 7, and Pl. II, fig. 12, a-b.

3. **Chromatium linsbaueri** Gicklhorn. (Ber. d. deut. botan. Ges., *39*, 1921, 312.) Named for the Austrian botanist, K. Linsbauer.

Cells: 6 by up to 15 microns (Gicklhorn); 6 to 8 microns in width (Ellis, Sulphur Bacteria, London and New York, 1932, 147). Special characteristic is the occurrence of calcium carbonate inclusions. Otherwise resembles *Chromatium okenii*.

Source: From a pool in the Stiftingtal, near Graz, Austria.

Habitat: Fresh water.

Illustrations: Gicklhorn, *loc. cit.*, 314, fig. 1; Ellis, *loc. cit.*, 148, fig. 31.

4. **Chromatium okenii** (Ehrenberg) Perty. (*Monas okenii* Ehrenberg, Infusionsthierchen, Leipzig, 1838; Perty, Zur Kenntniss kleinster Lebensformen, Bern, 1852, 174; *Bacillus okenii* Trevisan, I generi e le specie delle Batteriacee, 1889, 18; *Bacterium okenii* DeToni and Trevisan, in Saccardo, Sylloge Fungorum, *8*, 1889, 1027; *Pseudomonas okenii* Migula, in Engler and Prantl, Die natürlichen Pflanzenfamilien, *1*, 1a, 1895, 30.) Named for the German naturalist, L. Oken. This is the type species of genus *Chromatium*.

Cells: 5.6 to 6.3 by 7.5 to 15 microns (Cohn); minimum width 4.5 microns (Issatchenko, Borodin Jubilee Vol., 1929?, 8); with many transitions to *Chromatium weissei* (Winogradsky, Schwefelbacterien, Leipzig, 1888, 92). Also: 3.5 by 8 to 12 microns and varying in size from 1 to 15 microns (Manten, Antonie van Leeuwenhoek, *8*, 1942, 164).

Illustrations: Cohn, Beitr. Biol. Pfl., *1*, Heft 3, 1875, Pl. VI, fig. 12; Winogradsky, *loc. cit.*, Pl. IV, fig. 3-4; Issatchenko, Recherches sur les microbes de l'océan glacial arctique, Petrograd, 1914, Pl. II, fig. 9.

5. **Chromatium weissei** Perty. (Perty, Zur Kenntniss kleinster Lebensformen, Bern, 1852, 174; *Bacillus weissii* Trevisan, I generi e le specie delle Batteriacee, 1889, 18; *Bacterium weissii* DeToni and Trevisan, in Saccardo, Sylloge Fungorum, *8*, 1889, 1027.) Named for the zoologist, J. F. Weisse, consequently the more common spellings, *Chromatium weissii* or *C. weisii* are in error.

Cells: 4.2 by 5.7 to 11.5 microns (Perty); also 3 to 4 by 7 to 9 microns (Issatchenko, Borodin Jubilee Volume, 1929?, 8); transitions to *Chromatium okenii* (Winogradsky, Schwefelbacterien, Leipzig, 1888, 92); transitions to *Chromatium minus* (Strzeszewski, Bull. Acad. Sci., Cracovie, Sér. B. 1913, 321).

Illustrations: Winogradsky, *loc. cit.*, Pl. IV, fig. 1-2; Miyoshi, Jour. Coll. Sci., Imp. Univ. Tokyo, Japan, *10*, 1897, Pl. XIV, fig. 15.

6. **Chromatium cuculliferum** Gicklhorn. (Cent. f. Bakt., II Abt., *50*, 1920, 419.) From Latin *cucullus*, cap or hood and *fero*, to bear.

Cells: 4 by 6 to 8 microns (Gicklhorn); according to Bavendamm (Schwefelbakterien, Jena, 1924, 127) identical with *Chromatium warmingii* forma *minus*. Gicklhorn claims this organism to be colorless, which appears very doubtful.

Source: From the pond in the Annen Castle Park, Graz, Austria.

Habitat: Fresh water ponds.

Illustration: Gicklhorn, *loc. cit.*, fig. 2.

7. **Chromatium minus** Winogradsky. (Winogradsky, Schwefelbacterien, Leipzig, 1888, 99; *Bacillus minor* Trevisan, I generi e le specie delle Batteriacee, 1889, 18; *Bacterium minus* DeToni and Trevisan, in Saccardo, Sylloge Fungorum, *8*, 1889, 1027.) From Latin *minus*, small.

Cells: 3 by 3.5 to 7 microns (Winogradsky); also 1.7 to 3 microns in width and up to 8.5 microns in length (Issatchenko, Borodin Jubilee Volume, 1929?, 9); all transitions to *Chromatium weissei* from which it cannot be distinguished (Strzeszewski, Bull. Acad. Sci., Cracovie, Sér. B, 1913, 321).

Illustrations: Winogradsky, *loc. cit.*, Pl. IV, fig. 5; Miyoshi, Jour. Coll. Sci., Imp. Univ., Tokyo, Japan, *10*, 1897, Pl. XIV, fig. 16; Issatchenko, Recherches sur les microbes de l'océan glacial arctique, Petrograd, 1914, Pl. II, fig. 10–11.

8. **Chromatium vinosum** (Ehrenberg) Winogradsky. (*Monas vinosa* Ehrenberg, Die Infusionstierchen, Leipzig, 1838, 11; Winogradsky, Schwefelbacterien, Leipzig, 1888, 99; *Bacillus vinosus* Trevisan, I generi e le specie delle Batteriacee, 1889, 18; *Bacterium vinosum* DeToni and Trevisan, in Saccardo, Sylloge Fungorum, *8*, 1889, 1027.) From Latin *vinosus*, pertaining to wine, wine-colored.

Cells: 2 by 2.5 to 5 microns; also 1.4 to 3 by 1.5 to 5 microns (Jimbo, Botan. Magaz. Tokyo, *51*, 1937, 872); 1.7 to 2 by 2 to 9 microns (Issatchenko, Borodin Jubilee Volume, 1929?, 9); or 1 to 1.3 microns by 2.5 to 3 microns (Schrammeck, Beitr. Biol. d. Pflanzen, *22*, 1935, 317). Jimbo considers *Thioderma roseum* Miyoshi to be identical with *Chromatium vinosum*.

Illustrations: Winogradsky, *loc. cit.*, Pl. IV, 6–7; Miyoshi, Jour. Coll. Sci., Imp. Univ. Tokyo, Japan, *10*, 1897, Pl. XIV, fig. 17; Nadson, Bull. Jard. Imp. Botan., St. Pétersbourg, *12*, 1912, Pl. III, fig. 1–2.

9. **Chromatium violaceum** Perty. (Zur Kenntniss kleinster Lebensformen, Bern, 1852, 174.) From Latin *violaceus*, violet-colored.

Cells: About 2 by 2 to 3 microns. According to Cohn (Beitr. Biol. Pfl., *1*, Heft 3, 1875, 166) probably identical with *Chromatium vinosum*. Apparently includes various sizes.

10. **Chromatium molischii** (Bersa) *comb. nov.* (*Pseudomonas molischii* Bersa, Planta, *2*, 1926, 375.) Named for the Austrian botanist, H. Molisch.

Cells: About 2 by 2.5 to 8 microns. Supposedly contains calcium carbonate as inclusions.

Illustration: Bersa, *loc. cit.*, 376, fig. 3.

11. **Chromatium gracile** Strzeszewski. (Bull. Acad. Sci., Cracovie, Sér. B, 1913, 321.) From Latin *gracilis*, slender.

Cells: 1 to 1.3 by 2 to 6 microns; also to 1.5 micron in width (Issatchenko, Études microbiologiques des Lacs de Boue, Leningrad, 1927, 114).

Illustration: Strzeszewski, *loc. cit.*, Pl. XXXIX, fig. 1–2; Tokuda, Botan. Magaz., Tokyo, *50*, 1936, 339, fig. 1–23.

12. **Chromatium minutissimum** Winogradsky. (Winogradsky, Schwefelbac-

terien, Leipzig, 1888, 100; *Bacillus minutissimus* Trevisan, I generi e le specie delle Batteriacee, 1889, 18; *Bacterium minutissimum* DeToni and Trevisan, in Saccardo, Sylloge Fungorum, *8*, 1889, 1028.) From Latin *minutus* and diminutive, very minute.

Cells: About 1 to 1.2 micron by 2 microns. Also from 0.5 to 0.7 micron by 0.6 to 1 micron (Issatchenko, Recherches sur les microbes de l'océan glacial arctique, Petrograd, 1914, 253); and 1 to 3 microns by 2 to 5 microns (Issatchenko, Borodin Jubilee Volume, 1929?, 9).

Illustrations: Winogradsky, *loc. cit.*, Pl. IV, fig. 8; Miyoshi, Jour. Coll. Sci., Imp. Univ., Tokyo, Japan, *10*, 1897, Pl. XIV, fig. 18.

Appendix: The measurements for *Thiospirillum coccineum* Hama (Jour. Sci. Hiroshima Univ., Ser. B, Div. 2, Bot., *1*, 1933, 158) which, according to description and figures (*ibid.*, Pl. 18, fig. 2; Pl. 19, fig. 2), is an unquestionable species of *Chromatium*, are given as 2 by 4 to 15 microns. It thus closely resembles the bacteria of the *Chromatium minus*, *C. vinosum*, *C. violaceum*, and *C. molischii* group.

Chromatium sphaeroides Hama, *loc. cit.*

Thiospirillum violaceum (Warming) Winogradsky is probably also a member of this assemblage.

APPENDIX TO FAMILY THIORHODACAE.

Three genera of sulfur purple bacteria have been proposed whose place and nature are at present very doubtful. They follow here:

a. *Thiosphaerion* Miyoshi, with the single species *Thiosphaerion violaceum* Miyoshi (Jour. Coll. Sci., Imp. Univ., Tokyo, Japan, *10*, 1879, 170). Occurs in round colonies in which numerous bacteria are held together by mucus, though not in a clearly discernible common capsule. Individual cells ovoid, about 1.5 to 2 by 2.5 microns; motile. Resembles *Lamprocystis roseopersicina* in many respects. Reported once from Yumoto Hot Springs, near Nikko, Japan.

Illustrations: Miyoshi, *loc. cit.*, Pl. XIV, fig. 24 a-b.

b. *Pelochromatium* Lauterborn, with the single species *Pelochromatium roseum* Lauterborn (Verhandl. naturhist. medizin. Vereins, Heidelberg, N.F. *13*, 1915, 424). Forms small colonies in which the bacteria are regularly arranged in about 5 rows, from 2 to 4 cells high, around a colorless central body. The entire colony actively motile and behaves like a single unit. Individual cells bean- or vibrio-shaped, about 1 micron or less by 2 microns; the barrel-shaped colony measures 2.5 to 4 by 4 to 8 microns. The structure may represent a complex of a colorless central bacterium surrounded by purple bacteria, analogous to *Chlorochromatium aggregatum* Lauterborn. Whether such structures have generic or even specific taxonomic significance remains to be determined. The lack of information concerning the occurrence of sulfur globules in the cells makes it doubtful whether the organisms are sulfur purple bacteria at all. Found twice by Lauterborn in mud samples.

Illustrations: Lauterborn, *loc. cit.*, Pl. III, fig. 28, a-c.

Utermöhl suggested the name *Lauterborniola minima* Utermöhl (Biol. Zentralbl., *43*, 1924, 605) for the small brownish bacteria which form the covering of the central body of *Pelochromatium roseum*; according to this author the central body is a larger bacterium, 1.5 by 7 microns which he named *Endosoma palleum*.

c. *Thioporphyra* Ellis, with the single species *Thioporphyra volutans* Ellis (Jour. Roy. Technic. Coll. Glasgow,

1926, 165). The account of this pleomorphic organism, which is claimed to multiply by fission, budding, and probably spore formation, is wholly unconvincing. The shape and size of some of the cells make it appear likely that Ellis observed mixtures of various kinds of purple sulfur bacteria.

Illustrations: Ellis, *loc. cit.*, 166, fig. 1-14; 171, Micro. I; 172, Micro. II; Sulphur Bacteria, London and New York, 1932; 153, fig. 33; 154, fig. 34; 156, fig. 35; 158, fig. 36.

Finally, there exist some, as yet unnamed, red to purple bacteria which contain bacteriochlorophyll and carotenoid pigments, are capable of photosynthesis in the presence of hydrogen sulfide, but excrete elementary sulfur as an intermediate oxidation product instead of storing sulfur globules inside their cells (van Niel, Arch. f. Mikrobiol., *3*, 1931, 63). They are small motile rods, vibrios or spirilla, about 0.5 by 1 to 2 microns. They may also occur as spherical cells of about 1 micron in diameter. They can readily be grown in organic media, under anaerobic conditions, in illuminated cultures and may be included either with the sulfur purple bacteria or with the non-sulfur purple bacteria, among which *Rhodopseudomonas palustris* is equally capable of photosynthesis in the presence of reduced inorganic sulfur compounds.

FAMILY II. ATHIORHODACEAE MOLISCH.*

(Molisch, Die Purpurbakterien, Jena, 1907, 28; *Rhodobacterioideae* Buchanan, Jour. Bact., *3*, 1918, 471; *Athiorhodobacteria* Bavendamm, Ergeb. Biol., *13*, 1936, 49.)

Unicellular bacteria, of relatively small size, occurring as spheres, short rods, vibrios, long rods and spirals. Motility is due to the presence of polar flagella. Gram-negative. They produce a pigment system composed of bacteriochlorophyll and one or more carotenoids, coloring the cells yellowish-brown, olive brown, dark brown or various shades of red. Color usually not observable with single cells but only with cell masses. Generally microaerophilic, although many representatives may grow at full atmospheric oxygen tension. Capable of development under strictly anaerobic conditions, but only in illuminated cultures by virtue of a photosynthetic metabolism. The latter is dependent upon the presence of extraneous hydrogen donors, such as alcohols, fatty acids, hydroxy- and keto-acids, and does not proceed with the evolution of molecular oxygen. Those members which can grow in the presence of air can also be cultivated in darkness, but only under aerobic conditions.

Key to the genera of family **Athiorhodaceae.**

I. Cells rod-shaped or spherical, not spiral-shaped.
  Genus I. *Rhodopseudomonas*, p. 861.

II. Cells spiral-shaped.
  Genus II. *Rhodospirillum*, p. 866.

Genus I. **Rhodopseudomonas** *Kluyver and van Niel emend. van Niel.*

(Includes *Rhodobacillus* Molisch, Die Purpurbakterien, Jena, 1907, 14; *Rhodobacterium* Molisch, *ibid.*, 16; *Rhodococcus* Molisch, *ibid.*, 20; *Rhodovibrio* Molisch, *ibid.*, 21; *Rhodocystis* Molisch, *ibid.*, 22; *Rhodonostoc* Molisch, *ibid.*, 23; *Rhodosphaera* Buchanan, Jour. Bact., *3*, 1918, 472; *Rhodorrhagus* Bergey et al., Manual, 3rd ed., 1930, 535; *Rhodomonas* Kluyver and van Niel, Cent. f. Bakt., II Abt., *94*, 1936, 397; not *Rhodomonas* Orla-Jensen, Cent. f. Bakt., II Abt., *22*, 1909, 331; Kluyver and van Niel, in Czurda and Maresch, Arch. f. Mikrobiol., *8*, 1937, 119; van Niel, Bact. Rev., *8*, 1944, 86.) From Greek *rhodon*, red and *pseudomonas*, false unit.

Spherical and rod-shaped bacteria, motile by means of polar flagella. Gram-negative. Contain bacteriochlorophyll which enables them to carry out a photosynthetic metabolism. The latter is dependent upon the presence of extraneous oxidizable substances and proceeds without the evolution of molecular oxygen. Though some members can oxidize inorganic substrates, none appears to be strictly autotrophic, due to the need for special organic growth factors. Produce accessory pigments causing the cultures, especially when kept in light, to appear in various shades of brownish-yellow to deep red.

The genus includes the members of Molisch's genera *Rhodobacterium*, *Rhodobacillus*, *Rhodovibrio*, *Rhodocystis*, *Rhodonostoc* and *Rhodococcus*, as well as the genera *Rhodosphaera* Buchanan, *Rhodorrhagus* Bergey et al. and *Rhodomonas* Kluyver and van Niel.

The type species is *Rhodopseudomonas palustris* (Molisch) van Niel.

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* Completely revised by Prof. C. B. van Niel, Hopkins Marine Station, Pacific Grove, California, January, 1944.

Keys to the species of genus **Rhodopseudomonas.**

I. Based upon morphological characters.
  1. Cells clearly rod-shaped in all media.
    a. Cells short, somewhat curved, to long branched rods, size of young and short cells 0.6 to 0.8 by 1.2 to 2 microns; in older cultures up to 10 microns long; do not form slime; liquid cultures, when young, or after shaking, evenly turbid. Color red to dark brown-red.
      1. *Rhodopseudomonas palustris.*
    aa. Cells slender rods, 0.5 by 1.2 microns usually clumped together in extensive slime masses. Cultures pale brown to peach-colored.
      2. *Rhodopseudomonas gelatinosa.*
  2. Cells more or less spherical in media at pH below 7.
    a. In media at pH about 7 clearly rod-shaped, 1 by 1 to 2.5 microns. Chains of cells frequent, and in characteristic zigzag arrangement.
      3. *Rhodopseudomonas capsulatus.*
    aa. In media at pH above 7 cells still predominantly spherical, 0.7 to 4 microns in diameter. Mostly single, little tendency to chain formation.
      4. *Rhodopseudomonas spheroides.*

II. Based chiefly on physiological properties.
  1. Gelatin liquefied.
      2. *Rhodopseudomonas gelatinosa.*
  2. Gelatin not liquefied.
    a. Does not produce mucus in media at pH above 8. Color the same under aerobic and anaerobic conditions of growth.
      1. *Rhodopseudomonas palustris.*
    aa. Produce mucus in media at pH above 8. Color brown in anaerobic, red in aerobic culture.
      b. Develops readily in media with 0.2 per cent propionate as the chief oxidation substrate. Mucus production marked at pH above 8, but very limited between 7 and 8.
        3. *Rhodopseudomonas capsulatus.*
      bb. Does not develop in media with 0.2 per cent propionate as the main oxidation substrate. Slime formation extensive at pH above 7.
        4. *Rhodopseudomonas spheroides.*

III. Based principally upon biochemical characters.
  1. Thiosulfate used as main oxidation substrate.
      1. *Rhodopseudomonas palustris.*
  2. Thiosulfate not used.
    a. Propionate (0.2 per cent) used.
      3. *Rhodopseudomonas capsulatus.*
    aa. Propionate not used.
      b. Mannitol and sorbitol (0.2 per cent) used.
        4. *Rhodopseudomonas spheroides.*
      bb. Mannitol and sorbitol not used.
        2. *Rhodopseudomonas gelatinosa.*

1. **Rhodopseudomonas palustris** (Molisch) van Niel. (*Rhodobacillus palustris* Molisch, *Rhodobacterium capsulatum* Molisch and *Rhodovibrio parvus* Molisch, Die Purpurbakterien, Jena, 1907, 14, 18 and 21; *Rhodomonas palustris* Kluyver and van Niel, Cent. f. Bakt., II Abt., *94*, 1936, 397; *Rhodopseudomonas* No. 9 and No. 16, Czurda and Maresch, Arch. f. Mikrobiol., *8*, 1937, 120; van Niel, Bact. Rev., *8*, 1944, 89.) From Latin *paluster*, boggy, marshy.

Cells: Usually distinctly rod-shaped, though in young cultures very short, lightly curved rods may often predominate. Size variable, even for the same strain, and strongly influenced by age of culture and composition of medium. Rather consistently short cells in young cultures in yeast extract, especially when incubated anaerobically in the light, or in anaerobic cultures with substrates which permit only a slow and scanty development, such as malonate. Dimensions in such cultures 0.6 to 0.8 by 1.2 to 2 microns. More often, especially in older cultures, cells are much longer, up to 10 microns. Highly characteristic is the pronounced tendency to the formation of irregularly shaped, bent and crooked long rods, occasionally swollen at one or both extremities, and frequently suggesting branching. Such cells usually form clusters reminiscent of *Corynebacterium* and *Mycobacterium* cultures.

Cells in young cultures actively motile by means of polar flagella; irregular and long cells as a rule non-motile. Gram-negative.

Growth in liquid media never mucoid; sediment in older cultures homogeneous and smooth, readily redispersible.

Color: Varies considerably, depending upon the medium, and especially in anaerobic illuminated cultures. Where development is slight (as in malonate, thiosulfate, and, usually, glycerol media), the color is a light pink; in fatty acid-containing media more nearly dark reddish-brown. Color due to bacteriochlorophyll and a number of different carotenoid pigments; most strains produce in addition a water-soluble, non-carotenoid, bluish-red pigment which diffuses into the culture medium.

In yeast extract cultures growth is possible over the range pH 6 to 8.5. With certain substrates, especially fatty acids, the combined effect of low pH and a substrate concentration of 0.1 to 0.2 per cent may prevent growth. No characteristic odors save that old cultures may develop a distinct ionone-like fragrance. Gelatin is not liquefied; leucine is generally utilized as a substrate.

Most strains are able to grow on the surface of agar plates or slants; a few, especially when first isolated, appear more sensitive to oxygen and develop only in stabs in which the upper region may remain free of growth. Generally such strains can be adapted to grow at full atmospheric oxygen tension.

Most fatty acids and hydroxy acids are adequate oxidation substrates. All cultures can grow at the expense of thiosulfate and produce rapid and profuse growth in glutarate and ethanol media. No development in media containing as the chief oxidation substrate 0.2 per cent sorbitol, glucose or mannose, even though these substances are not inhibitory. Molecular hydrogen can be oxidized.

All cultures can develop anaerobically in illuminated cultures by photosynthesis.

Temperature optimum generally rather high, good development being possible up to 37°C. However, certain strains exhibit a lower temperature optimum.

Distinguishing characteristics: Morphological resemblance to species of *Mycobacterium* in old cultures; ability to grow with thiosulfate as the chief oxidizable substrate, and failure to develop in media which contain carbohydrates or sugar alcohols in a concentration of 0.2 per cent as the main oxidizable compounds.

Habitat: Regularly found in mud and stagnant bodies of water.

Illustrations: Molisch, *loc. cit.*, Plate I, fig. 1, 2; Plate II, fig. 10; van Niel, *loc. cit.*, fig. 1–3, p. 18, and fig. 18–26, p. 90.

2. **Rhodopseudomonas gelatinosa** (Molisch) van Niel. (*Rhodocystis gelatinosa* Molisch, Die Purpurbakterien, Jena, 1907, 22; van Niel, Bact. Rev., *8*, 1944, 98.) From Latin *gelatio*, freezing, indicating solidification, or in this case, clumping.

Cells: In young cultures, short and small rods, approximately 0.5 by 1 to 2 microns. In old cultures much longer, up to 15 microns, and then irregularly curved rods, often swollen and gnarled in places up to 1 micron in width. In this stage the cells bear some resemblance to those found in old cultures of *Rhodopseudomonas palustris*, but the characteristic *Mycobacterium*-like clusters of the latter are absent. Single cells infrequent due to a copious mucus production in all media which causes the cells to clump together. While young cells are actively motile by means of polar flagella, motility is often difficult to ascertain as a result of the pronounced tendency to conglomerate; the individuals in the clumps appear to be non-motile. Gram-negative. Gelatin is liquefied; of the single amino acids alanine, asparagine, aspartic and glutamic acids appear generally satisfactory substrates.

Color: Quite distinctive in most anaerobic cultures as a pale, delicate, pinkish shade, rather peach-colored. Only in the presence of rather high concentrations of yeast extract (when a much heavier growth is obtained than with low concentrations supplemented with 0.2 per cent of various single oxidation substrates) do the slimy cell masses appear a dirty, faded brown. Color is due to bacteriochlorophyll and carotenoid pigments. Occasionally a water-soluble, non-carotenoid, bluish-red pigment is produced which diffuses into the culture medium.

In yeast extract, growth occurs over a pH range extending from at least 6.0 to 8.5.

Cultures produce a characteristic acrid odor.

More sensitive to fatty acids than other species of *Rhodopseudomonas*; with 0.2 per cent propionate no growth occurs. The best single oxidizable substrates appear to be ethanol, glucose, fructose and mannose, as well as a variety of amino acids. Citrate also permits good growth; not, on the other hand, glycerol, mannitol, sorbitol or tartrate in the usual concentration of 0.2 per cent.

Thiosulfate is not oxidized; behavior towards molecular hydrogen unknown.

More pronouncedly microaerophilic than the other *Rhodopseudomonas* species; most cultures cannot develop on aerobically incubated slants or agar plates.

Capable of strictly anaerobic development in illuminated cultures by virtue of a photosynthetic metabolism.

Temperature relations so far unknown.

Distinguishing properties: The small size of the individual cells, and the pronounced clumping which causes the cultures to be exceptionally stringy; the unusual color of the cell masses; the ability to liquefy gelatin, to utilize citrate and a number of amino acids. Correlated with these is the failure to grow in media with 0.2 per cent propionate, tartrate and glycerol.

Habitat: Regularly present in stagnant bodies of water and in mud.

Illustrations: Molisch, *loc. cit.*, Plate I, fig. 8; van Niel, *loc. cit.*, fig. 55–60, p. 99; fig. 61–66, p. 100.

3. **Rhodopseudomonas capsulatus** (Molisch) van Niel. (*Rhodonostoc capsulatum* Molisch, Die Purpurbakterien, Jena, 1907, 23; van Niel, Bact. Rev., *8*, 1944, 92.) From Latin *capsula*, container (sheath).

Cells: Depending upon the pH of the medium, cells nearly spherical, or as distinct rods, often devoid of motility. Motility due to polar flagella. The spherical cells are found in media with a pH below 7; they are usually arranged in chains resembling streptococci. Rod-shaped cells are characteristic for media with pH above 7; the higher the pH, the longer the rods. Individual cells slightly less than 1 micron wide, although attenuated rods (about 0.5 micron in width) are frequent at pH above 8, and slightly swollen cells (to 1.2 microns) are found in media containing sugars. Length varies from 1 to 6 microns; most common dimensions in approximately neutral media 2 to 2.5 microns. At pH above 8 abnormal growth in the form of irregular filaments. Outstandingly characteristic is the zigzag arrangement of the cells in chains.

Cultures in media of pH 8 or above are distinctly mucoid. Gram-negative.

Color: Anaerobic cultures develop with a brown color, the shade ranging from a light yellowish-brown to a deep mahogany brown. When grown in the presence of oxygen, the cultures are dark red. Even the pigmentation of the brown-colored organisms from an anaerobic culture can be changed into a distinct red by shaking a suspension with air for some hours; light enhances the rate of this color change. Color due to bacteriochlorophyll and carotenoid pigments. No diffusible water-soluble pigment is produced.

Growth possible over a pH range from at least 6 to 8.5, morphology becoming abnormal in the alkaline media.

Most cultures are odorless, although occasionally a faint peach-like odor can be detected.

Growth is not inhibited by the presence of oxygen, although the pigmentation is thereby affected.

Fatty acids and most substituted acids are satisfactory substrates. Rapid and abundant growth with propionate at a concentration of 0.2 per cent. At this same concentration glutaric acid leads, at best, to very meager cultures, while tartrate, citrate and gluconate fail to induce growth, as do also ethanol, glycerol, mannitol and sorbitol. In media with 0.2 per cent glucose or fructose good growth is obtained. No growth with mannose. Thiosulfate is not, but molecular hydrogen can be, oxidized by this species.

Gelatin is not liquefied; of the amino acids alanine and glutamic acid are satisfactory substrates, while leucine is not utilized.

Distinguishing properties: Cell shape and arrangement in chains; brown color of anaerobic, red pigmentation of aerobic cultures; ability to grow in media with 0.2 per cent propionate, glucose, fructose, alanine and glutamic acid; failure to develop with leucine, as well as with ethanol, glycerol, mannitol and sorbitol in the above-mentioned concentration.

All cultures can develop anaerobically in illuminated cultures by a photosynthetic metabolism.

Temperature optimum distinctly lower than for *Rhodopseudomonas palustris*, and, as a rule, around 25°C.

Habitat: Regularly found in stagnant bodies of water and in mud.

Illustrations: Molisch, *loc. cit.*, Plate II, fig. 9; van Niel, *loc. cit.*, fig. 4–6, p. 19; fig. 27–32, p. 92; and fig. 33–38, p. 93.

4. **Rhodopseudomonas spheroides** van Niel. (*Rhodococcus capsulatus* Molisch, Die Purpurbakterien, Jena, 1907, 20; *Rhodococcus minor* Molisch, *ibid.*, 21; *Rhodosphaera capsulata* Buchanan, Jour. Bact., *3*, 1918, 472; *Rhodosphaera minor* Bergey et al., Manual, 1st ed., 1923, 405; *Rhodorrhagus minor* Bergey et al., Manual, 3rd ed., 1930, 535; *Rhodorrhagus capsulatus* Bergey et al., Manual, 3rd ed., 1930, 535; van Niel, Bact. Rev., *8*, 1944, 95.) From Latin *sphaera*, a round body and Greek *eidos*, form of.

Cells: Generally single, nearly spherical, diameter without slime capsule variable, depending upon medium, ranging from 0.7 to 4 microns. In young cultures actively motile by means of polar flagella; motility soon ceases in media which are or become alkaline. Copious slime production in media at pH above 7. In strongly alkaline cultures abnormal cell-shapes occur in the form of irregular, swollen and distorted rods, often having the appearance of spore-bearing cells, simulated by the production of fat bodies. In sugar-containing media egg-shaped cells, measuring as a rule 2.0 to 2.5 by 2.5 to 3.5 microns, are frequently found. Gram-negative.

Color: Anaerobic cultures develop with brown color, ranging in shade from a light, dirty greenish-brown to a dark brown. Cultures grown in the presence of oxygen are distinctly red. As in the case of *Rhodopseudomonas capsulatus*, the brown color of an anaerobic culture can be changed to red by shaking with air, light stimulating the color change. Color due to bacteriochlorophyll and carotenoid pigments. The large majority of cultures of this species produces in addition a water-soluble, non-carotenoid, bluish-red pigment which diffuses into the culture medium.

Gelatin is not liquefied, and growth with single amino acids appears somewhat erratic. No definite correlations have been observed.

Development is possible over a wide pH range, extending from at least 6.0 to 8.5.

All cultures exhibit an unpleasant putrid odor.

Requires for optimal development higher concentrations of yeast extract as a supply of growth factors than either *Rhodopseudomonas palustris* or *Rhodopseudomonas capsulatus* and is more sensitive to low fatty acid concentrations. With 0.2 per cent propionate in a neutral medium, no growth occurs; caproic and pelargonic acids are toxic in concentrations below 0.1 per cent. On the other hand, tartrate and gluconate can serve as oxidation substrates, as can also ethanol, glycerol, mannitol, sorbitol, glucose, fructose and mannose in 0.2 per cent concentrations.

In sugar-containing media, acid is produced; the pH may drop to below 4.0 before development ceases. Acid production from glucose occurs both in presence and absence of air, and in illuminated as well as in non-illuminated cultures. In cultures exposed to light, the acid usually disappears later on.

Thiosulfate is not oxidized; hydrogen oxidation has not been observed.

Oxygen does not prevent growth; colonies develop on the surface of agar plates exposed to air, with a red pigmentation. Capable of strictly anaerobic development in illuminated cultures by photosynthesis.

Temperature optimum below 30°C.

Distinguishing properties: Spherical cell-shape in most media; brown color of anaerobic and red pigmentation of aerobic cultures; growth with 0.2 per cent tartrate, gluconate, ethanol, glycerol, mannitol, sorbitol, glucose, fructose and mannose; failure to grow with 0.2 per cent propionate.

Habitat: Regularly found in stagnant bodies of water and in mud.

Illustrations: Molisch, *loc. cit.*, Plate II, fig. 15; van Niel, *loc. cit.*, fig. 7–8, p. 19; fig. 39–45, p. 96; fig. 46–54, p. 97.

Genus II. **Rhodospirillum** *Molisch emend. van Niel.*

(Molisch, Die Purpurbakterien, Jena, 1907, 24; van Niel, Bact. Rev., *8*, 1944, 86; the genus now includes the genus *Phaeospirillum* Kluyver and van Niel, Cent. f. Bakt., II Abt., *94*, 1936, 396.) From Greek *rhodon*, red and M.L. *spirillum*, spirillum.

Spiral-shaped bacteria, motile by means of polar flagella. Gram-negative.

Contain bacteriochlorophyll and are potentially photosynthetic in the presence of extraneous oxidizable substances. Molecular oxygen is not produced. Unable to grow in strictly mineral media, even when possessed of the ability to utilize hydrogen as oxidizable substrate, due to the need for organic nutrilites. Produce accessory pigments causing the cultures, especially when grown in the light, to appear in various shades of red to brown.

The type species is *Rhodospirillum rubrum* (Esmarch) Molisch.

Key to the species of genus **Rhodospirillum.**

I. Cultures red; cells well over 0.5 micron, usually about 1 to 1.2 microns in width.
1. *Rhodospirillum rubrum.*

II. Cultures brown to orange; cells 0.5 micron or less in width.
2. *Rhodospirillum fulvum.*

1. **Rhodospirillum rubrum** (Esmarch) Molisch. (*Spirillum rubrum* Esmarch, Cent. f. Bakt., *1*, 1887, 225; Molisch, Die Purpurbakterien, Jena, 1907, 25; *Rhodospirillum photometricum* Molisch, *ibid.*, 24; *Rhodospirillum giganteum* Molisch, *ibid.*, 24; *Rhodospirillum longum* Hama, Jour. Sci. Hiroshima Univ., Ser. B, Div. 2, *1*, 1933, 135; *Rhodospirillum gracile* Hama, *ibid.*, 159.) From Latin *ruber*, red.

Cells: Characteristically spiral-shaped, but size of elements variable within wide limits, depending upon environmental conditions during growth. Width of cells from 0.5 to 1.5 microns; length from 2 to 50 microns, and over; even in a single culture such differences may be found. Also the shape and size of the spiral coil varies much; it usually ranges between 1 to 4 microns in width, and from 1.5 to 7 microns in length. In alanine media the majority of the cells occurs in the form of half-circles to complete rings; malate media tend to produce much flattened spirals.

In old cultures involution forms appear, straightened spirals and irregularly swollen cells, the latter common in media with higher fatty acids. Such cells stain irregularly, contain fatty inclusions, and are occasionally branched.

Mucus is not produced. In calcium-deficient media the growth is flocculent, as if agglutinated. With an adequate calcium supply the growth in liquid media is homogeneous, suspended, and consists of single cells.

Young cultures show active motility, due to polar flagella. Gram-negative.

Gelatin is not liquefied; the amino acids alanine, asparagine, aspartic and glutamic acids are satisfactory oxidizable compounds.

Color: Ordinarily deep and dark red, without any brownish tinge. In ethanol media lighter, and a characteristic pink. Pigment production markedly influenced by oxygen and light. Slants incubated in darkness present a pale grayish surface growth with a faint reddish hue, while often showing deep-red cell masses in the region between glass wall and agar surface where development proceeds at low oxygen tension. The color is due to bacteriochlorophyll and carotenoid pigments. Among the latter spirilloxanthin is quantitatively predominant. Water-soluble, diffusible pigments are not produced.

Development possible over a pH range of at least 6 to 8.5, although, as in other cases, the combination of an acid reaction and the presence of fatty acids may prevent growth.

Cultures produce a distinctive odor, reminiscent of slightly putrid yeast.

In general, grow well with fatty acids as the chief oxidizable substrate; however, are prevented from growing by 0.2 per cent propionate in a neutral medium. Most substituted acids are equally satisfactory, with the exception

of tartrate, gluconate and citrate. In a concentration of 0.2 per cent, ethanol is a suitable substrate, whereas the carbohydrates and their corresponding polyalcohols are not utilized.

Thiosulfate is not oxidized; molecular hydrogen can be used by some strains.

Rather microaerophilic; many strains upon initial isolation incapable of growth at atmospheric oxygen tension. Subsequent adaptation can be induced. But even such adapted cultures exhibit negative chemotaxis to air.

Capable of strictly anaerobic development in illuminated cultures on the basis of a photosynthetic metabolism.

Temperature optimum generally between 30° and 37°C.

Distinguishing properties: The most important characteristics of the species are the spiral shape, combined with the ability to produce a red pigment with a definite absorption maximum at 550 millimicrons in the intact cells. Diagnostically useful are the good growth in media with 0.2 per cent ethanol, alanine, asparagine, aspartate or glutamate, and the inadequacy of similar concentrations of carbohydrates and thiosulfate as substrates.

Habitat: Regularly present in stagnant bodies of water and in mud.

Illustrations: Molisch, *loc. cit.*, Plate I, fig. 5-7; van Niel, Bact. Rev., *8*, 1944, fig. 9–10, p. 19; fig. 11–16, p. 24; fig. 67–75, p. 103; fig. 76-84, p. 104; fig. 85–90, p. 106; fig. 91–96, p. 107.

2. **Rhodospirillum fulvum** van Niel. (Bact. Rev., *8*, 1944, 108.) From Latin *fulvum*, yellowish, tawny.

Characteristic for the species is the very small size of the individual cells. These are not over 0.5 micron wide, and generally not longer than 2.5 microns. The most common shape consists of a complete turn of about 1 by 1.5 microns. In media with fatty acids as a substrate the spirals appear somewhat steeper than in fumarate, succinate or malate cultures. Swollen individuals resembling vibrios are encountered in cultures which do not appear quite healthy. Formation of mucus or clumping has not been observed.

Gelatin is not liquefied; aspartate has been the only amino acid capable of inducing growth. Thiosulfate is not oxidized.

Color: Quite distinct from that of *Rhodospirillum rubrum*; colonies and stab cultures are a reddish-brown, while liquid cultures often appear brownish-orange. The color is due to bacteriochlorophyll and carotenoid pigments; among the latter spirilloxanthin, as evidenced by the absence of an absorption maximum at 550 millimicrons, is not represented as a major constituent. Does not produce water-soluble, diffusible pigments.

Capable of strictly anaerobic development in illuminated cultures, due to photosynthetic metabolism.

Fatty acids and the four-carbon dicarboxylic acids are uniformly good substrates; glutarate is not used. Ethanol and glucose, in a concentration of 0.2 per cent, have yielded satisfactory cultures; other carbohydrates, as well as the corresponding polyalcohols, have given negative results.

Little information available concerning pH and temperature relations. Behaves generally as a strict anaerobe; adaptation to microaerophilic conditions has not been achieved. Negative aerotaxis very pronounced.

Distinguishing properties: The small size and the color of the cultures serve as adequate criteria for its differentiation from *Rhodospirillum rubrum*. The strictly anaerobic nature and the failure to grow with glutarate and various amino acids except aspartate can probably be used as supplementary specific properties.

Habitat: Bodies of stagnant water and mud.

Illustrations: Van Niel, *loc. cit.*, fig. 97–102, p. 109.

FAMILY III. CHLOROBACTERIACEAE GEITLER AND PASCHER.*

(*Cyanochloridinae-Chlorobacteriaceae* Geitler and Pascher, Die Süsswasserflora Deutschlands, Österreichs und der Schweiz, Jena, *12*, 1925, 451; *Chlorothiobacteria* Bavendamm, Ergeb. Biol., *13*, 1936, 49.)

Green bacteria, usually of small size, occurring singly or in cell masses of various shapes and sizes, developing in environments containing rather high concentrations of hydrogen sulfide and exposed to light. As a rule not containing sulfur globules but frequently depositing elementary sulfur outside the cells. Contain green pigments of a chlorophyllous nature, though not identical with the common green plant chlorophylls nor with bacteriochlorophyll. Capable of photosynthesis in the presence of hydrogen sulfide; do not liberate oxygen.

A number of genera have been proposed, characterized by special colonial growth forms, others on the basis of a supposed symbiotic habitus, where the green bacteria grow in more or less characteristic aggregates together with other micro-organisms. In view of the variations in size and shape exhibited by the only member of this group which has so far been obtained and studied in pure culture (van Niel, Arch. f. Mikrobiol., *3*, 1931, 65ff.) the validity of many of these genera is doubtful. The following keys and descriptions, therefore, bear a strictly provisional character. Here, as in the case of the sulfur purple bacteria, significant advances can only be expected from pure culture studies under controlled environmental conditions.

Key to the genera of family **Chlorobacteriaceae.**

I. Free-living bacteria not intimately associated with other microbes.
  a. Bacteria not united into well defined colonies.
    Genus I. *Chlorobium*, p. 869.
  aa. Bacteria united into characteristic aggregates.
    b. Bacteria without intracellular sulfur globules.
      Genus II. *Pelodictyon*, p. 870.
    bb. Bacteria with intracellular sulfur globules.
      Genus III. *Clathrochloris*, p. 872.
II. Green bacteria found as symbiotic aggregates with other organisms.
  a. Aggregates composed of green bacteria and protozoa.
    Genus IV. *Chlorobacterium*, p. 872.
  aa. Aggregates composed of two different types of bacteria.
    b. Aggregates small, barrel-shaped, actively motile, and consisting of a central, polarly flagellated, rod-shaped bacterium with a covering of green sulfur bacteria.
      Genus V. *Chlorochromatium*, p. 873.
    bb. Aggregates large, cylindrical, non-motile, and composed of a central filamentous bacterium with a more or less extensive covering of green sulfur bacteria.
      Genus VI. *Cylindrogloea*, p. 873.

Genus I. **Chlorobium** *Nadson.*

(Nadson, Bull. Jard. Impér. Botan., St. Pétersb., *12*, 1912, 64 (Russian), 83 (German); *Chloronostoc* Pascher, Die Süsswasserflora Deutschlands, Österreichs und der Schweiz, Jena, *12*, 1925, 456; *Tetrachloris* Pascher, *ibid.*, 455; *Sorochloris*? Pascher,

* Completely revised by Prof. C. B. van Niel, Hopkins Marine Station, Pacific Grove, California, January, 1944.

ibid., 455; *Chloropseudomonas*? Czurda and Maresch, Arch. f. Mikrobiol., *8*, 1937, 123; in part, *Pelogloea* Lauterborn, Verhandl. naturhistor.-medizin. Vereins, Heidelberg, N.F. *13*, 1915, 430.) From Greek *chloros*, green and *bios*, life.

Green sulfur bacteria, occurring singly or in chains, individual cells of various sizes and shapes, from spherical to relatively long rod-shaped, the latter sometimes coiled into tight spirals; often united in chains, and generally embedded in a slime capsule. Non-motile. Contain a chlorophyllous pigment different from the common green plant chlorophylls and from bacterio-chlorophyll. Capable of photosynthesis in the presence of hydrogen sulfide, during which they produce elementary sulfur which is excreted outside the cells. Do not form spores.

The type species is *Chlorobium limicola* Nadson.

1. **Chlorobium limicola** Nadson. (Nadson, Bull. Jard. Impér. Botan., St. Pétersb., *12*, 1912, 64 (Russian), 83 (German); *Chloronostoc abbreviatum* Pascher, Süsswasserflora Deutschlands, Österreichs und der Schweiz, Jena, *12*, 1925, 456; *Tetrachloris inconstans* Pascher, *ibid.*, 456; *Sorochloris aggregata*? Pascher, *ibid.*, 455; in part *Pelogloea chlorina* Lauterborn, Verhandl. naturhistor.-medizin. Vereins, Heidelberg, N.F. *13*, 1915, 430.) From Latin, mud-dweller.

Cells: Various shapes and sizes, markedly dependent upon environmental conditions. In young and healthy state predominantly spherical to ovoid, about 0.5 to 1 micron in diameter, frequently united in chains resembling streptococci. Often cells become elongated and appear as rods, generally about 0.7 micron by 1 to 2.5 microns; also these may remain united in chains. Regularly produce mucus, causing the formation of cell-conglomerates of different size and shape, but not, as a rule, of characteristic appearance.

Color yellowish-green. Non-motile.

Abnormal cell forms (involution forms) rather common. These may be larger spherical cells, up to 5 to 6 microns in diameter, the larger ones generally vacuolated, or long rods, occasionally club-shaped but more often coiled. In rare cases the latter may be loosely wound. More frequently they are tightly-coiled screws, with cells of about 0.5 micron in diameter by as much as 15 microns in length. The spherical involution forms are normally encountered in acid, the coiled ones in alkaline environments.

Strictly anaerobic and apparently dependent upon hydrogen sulfide and light. Development in organic media has not been obtained.

Habitat: Mud and stagnant water containing rather high concentrations of hydrogen sulfide and exposed to light; more rarely in sulfur springs.

Illustrations: Nadson, *loc. cit.*, Pl. III, fig. 3–12; van Niel, Arch. f. Mikrobiol., *3*, 1931, 66, fig. 8.

Genus II. **Pelodictyon** *Lauterborn.*

(Lauterborn, Allgem. botan. Ztschr., *19*, 1913, 98; Verhandl. naturhistor.-medizin. Vereins, Heidelberg, N.F. *13*, 1915, 431; *Schmidlea loc. cit.*, Lauterborn, Allgem. botan. Zeitschr., *19*, 1913, 97; in part, *Pelogloea* Lauterborn, Verhandl. naturhist.-medizin Vereins, Heidelberg, N.F. *13*, 1915, 430; *Pediochloris* Geitler, Die Süsswasserflora Deutschlands, Österreichs und der Schweiz, Jena, *12*, 1925, 457.) From Greek *pelos*, mud and *dictyon*, net.

Green sulfur bacteria, individual cells ovoid to distinctly rod-shaped, producing rather extensive mucoid capsules, and generally united into large colonies of characteristic shapes. Non-motile. Contain chlorophyllous pigments different from

the common green plant chlorophylls and from bacteriochlorophyll. Capable of photosynthesis in the presence of hydrogen sulfide, but do not store sulfur globules inside the cells.

The type species is *Pelodictyon clathratiforme* (Szafer) Lauterborn.

Key to the species of genus **Pelodictyon.**

I. Cells united in colonies in a net-like fashion.
 1. *Pelodictyon clathratiforme.*

II. Cells arranged in tightly packed colonies without net-like structure.
 a. Colonies composed of irregularly arranged cell-masses, extending in three dimensions.
  2. *Pelodictyon aggregatum.*
 aa. Colonies consisting of parallel strands and extending in two dimensions.
  3. *Pelodictyon parallelum.*

1. **Pelodictyon clathratiforme** (Szafer) Lauterborn. (*Aphanothece clathratiforme* Szafer, Bull. Acad. Sci., Cracovie, Sér. B, *3*, 1910, 162; Lauterborn, Allgem. botan. Ztschr., *19*, 1913, 98; Lauterborn, Verhandl. naturhist.-medizin. Vereins, Heidelberg, N.F. *13*, 1915, 430; *Pelodictyon clathratiforme* Geitler, Die Süsswasserflora Deutschlands, Österreichs und der Schweiz, Jena, *12*, 1925, 458; *Pelodictyon lauterbornii* Geitler, *ibid.*, 458.) From Greek *clathros*, trellis and *formis*, shape.

Cells: Generally rod-shaped, ranging from slightly elongated ovoids to distinct rods, often vacuolated, about 0.5 to 1.5 micron by 2 to 4 microns, producing rather wide slime capsules, and characteristically united into three-dimensional colonies which present a net-like appearance, with mazes of about 10 to 50 microns.

Color yellowish-green. Non-motile.

Abnormal cell forms (involution forms) not uncommon, consisting of elongated and curved, forked, or club-shaped and swollen rods, occasionally suggesting rudimentary branching at the extremities. Such cells may be found as elements in chains for the greater part composed of normal individuals.

Habitat: Mud and stagnant water containing rather high concentrations of hydrogen sulfide and exposed to light; sulfur springs.

Illustrations: Szafer, *loc. cit.*, Pl. VI, fig. 5; Perfiliev, Jour. Microbiol. (Russian), *1*, 1914, Pl. II, fig. 1, 5–12; Lauterborn, *loc. cit.*, 1915, Pl. III, fig. 33.

2. **Pelodictyon aggregatum** Perfiliev. (*Aphanothece luteola* Schmidle, Beihefte Botan. Cent., *10*, 1901, 179; *Schmidlea luteola* Lauterborn, Allgem. botan. Ztschr., *19*, 1913, 97; Lauterborn, Verhandl. naturhistor.-medizin. Vereins, Heidelberg, N.F., *13*, 1915, 429; *Pelogloea bacillifera* Lauterborn, *ibid.*, 430; Perfiliev, Jour. Microbiol. (Russian), *1*, 1914, 197.) From Latin *aggregatus*, leading together, grouping.

Cells: Usually rod-shaped, about 1 to 1.5 microns by 2 to 4 microns, often vacuolated, producing mucus capsules, and united into irregularly shaped, three-dimensional colonies in which the cells are more or less tightly packed, without orderly arrangement. Colonies may attain a size of up to 1 mm; frequently they are not fully compact, but contain less dense areas, or appear perforated, thus forming transition stages to *Pelodictyon clathratiforme.*

Color yellowish-green. Non-motile.

Abnormal cell forms (involution forms) usually in the shape of elongated and curved, forked or club-shaped and swollen rods, occasionally suggesting branching at extremities.

Habitat: Mud and stagnant water, containing rather high concentrations of

hydrogen sulfide, and exposed to light; sulfur springs.

Illustrations: Perfiliev, *loc. cit.*, Pl. II, fig. 2; Lauterborn, *loc. cit.*, Pl. III, fig. 29–31.

3. **Pelodictyon parallelum** Perfiliev. (*Aphanothece parallela* Szafer, Bull. Acad. Sci., Cracovie, Sér. B, *3*, 1910, 163; Perfiliev, Jour. Microbiol. (Russian), *1*, 1914, 198; *Pediochloris parallela* Geitler, Die Süsswasserflora Deutschlands, Österreichs und der Schweiz, Jena, *12*, 1925, 457.) From Latin *parallelus*, beside one another.

Cells: Rather small, spherical to ovoid, or even rod-shaped; about 0.5 to 1 micron by 1 to 3 microns, occurring in chains, and forming flat, plate-like, two-dimensional aggregates in which the chains are arranged as parallel strands.

Color yellowish-green. Non-motile.

Abnormal cell forms not specifically mentioned, but likely to occur, and to resemble those of other species.

This species may well be a special growth-form of *Chlorobium limicola*.

Habitat: Mud and stagnant water containing rather high concentrations of hydrogen sulfide and exposed to light; sulfur springs.

Illustrations: Szafer, *loc. cit.*, Pl. VI, fig. 7; Perfiliev, *loc. cit.*, Pl. II, fig. 2.

Genus III. Clathrochloris *Geitler.*

(Die Süsswasserflora Deutschlands, Österreichs und der Schweiz, Jena, *12*, 1925, 457.) From Greek *clathros*, trellis and *chloros*, green.

Green sulfur bacteria of small size, generally spherical, and arranged in chains which are united into loose, trellis-shaped aggregates, somewhat similar to those of *Pelodictyon clathratiforme* and *Pelodictyon aggregatum*. Cells usually contain sulfur globules. Color yellowish-green. Non-motile.

The type species is *Clathrochloris sulphurica* (Szafer) Geitler.

1. **Clathrochloris sulphurica** (Szafer) Geitler. (*Aphanothece sulphurica* Szafer, Bull. Acad. Sci., Cracovie, Sér. B, *3*, 1910, 162; Geitler, Die Süsswasserflora Deutschlands, Österreichs und der Schweiz, Jena, *12*, 1925, 457.) From Latin, containing sulfur.

Cells: Spherical, about 0.5 to 0.7 micron in diameter, usually containing sulfur globules. Color yellowish-green. Non-motile.

The reported occurrence of sulfur globules in the cells of this very small species is surprising; it is the only one among the green sulfur bacteria in which these inclusions have been encountered. The published descriptions are even more fragmentary than those of other members of the group.

Source: Reported only from sulfur springs in Lubién Wielki, near Lwow, Poland.

Habitat: Mud and stagnant water containing rather high concentrations of hydrogen sulfide and exposed to light; sulfur springs.

Illustration: Szafer, *loc. cit.*, Pl. VI, fig. 6.

Genus IV. Chlorobacterium *Lauterborn.*

(Lauterborn, Verhandl. naturhist.-medizin. Vereins, Heidelberg, N.F., *13*, 1915, 429; not *Chlorobacterium* Guillebeau, Landw. Landw. Jahrb. d. Schweiz, *4*, 1890, 32; *Chroostipes* Pascher, Die Süsswasserflora Deutschlands, Österreichs und der Schweiz, Jena, *12*, 1925, 116.) From Greek *chloros*, green and Latin *bacterium*, a small rod.

Green sulfur bacteria(?) which grow symbiotically as an outside covering on cells of protozoa, such as amoeba and flagellates. Cells rod-shaped, often slightly curved, greenish. Non-motile.

The type species is *Chlorobacterium symbioticum* Lauterborn.

1. **Chlorobacterium symbioticum** Lauterborn. (Lauterborn, Verhandl. naturhist.-medizin. Vereins, Heidelberg, N.F., *13*, 1915, 429; *Chroostipes linearis* Pascher, Die Süsswasserflora Deutschlands, Österreichs und der Schweiz, Jena, *12*, 1925, 116.) From Greek, living symbiotically.

Cells: Rod-shaped, about 0.5 by 2 to 5 microns, often slightly curved. Non-motile.

Occur as a peripheral covering of certain protozoa with which they may form a symbiotic unit.

It is not certain that this is a green sulfur bacterium; the description of localities where it was found fail to mention the presence of hydrogen sulfide in the environment which should be a prerequisite for a member of this group.

Source: Reported from a number of pools in Germany.

Habitat: Stagnant water.

Illustrations: Lauterborn, *loc. cit.*, Pl. III, fig. 34–36; Pascher, *loc. cit.*, fig. 149.

Genus V. Chlorochromatium *Lauterborn.*

(Lauterborn, Allgem. botan. Ztschr., *19*, 1906, 196; *Chloronium* Buder, Ber. d. deut. bot. Ges., *31*, 1914, Generalversammlungsheft, 80.) From Greek *chloros*, green and *chroma*, color.

Green sulfur bacteria, ovoid to rod-shaped with rounded ends, occurring as barrel-shaped aggregates, consisting of a rather large colorless bacterium with a polar flagellum as the center, surrounded by the green bacteria, arranged in 4 to 6 rows, ordinarily from 2 to 4 cells high. The entire conglomerate behaves like a unit, is motile, and multiplies by the more or less simultaneous fission of its components.

The green constituents contain a chlorophyllous pigment which is not identical with the common green plant chlorophylls or with bacteriochlorophyll. Capable of photosynthesis in the presence of hydrogen sulfide, but do not store sulfur globules in the cells.

The type species is *Chlorochromatium aggregatum* Lauterborn.

1. **Chlorochromatium aggregatum** Lauterborn. (Lauterborn, Allgem. botan. Ztschr., *19*, 1906, 196; *Chloronium mirabile* Buder, Ber. deut. botan. Ges., *31*, 1914, Generalversammlungsheft, 80.) From Latin *aggregatus*, grouped.

Cells of the green component 0.5 to 1.0 by 1.0 to 2.5 microns, mostly from 8 to 16 individuals surrounding the central bacterium. Size of the total barrel-shaped unit variable, generally 2.5 to 5 by 7 to 12 microns. Occasionally a group of the complex colonies may remain attached in a chain.

Anaerobic.

Habitat: Mud and stagnant water containing rather high concentrations of hydrogen sulfide and exposed to light.

There is at present no good reason for distinguishing 2 varieties (forma *typica* and forma *minor*) or even species, on the basis of size differences of the colony, as Geitler proposed (Die Süsswasserflora Deutschlands, Österreichs und der Schweiz, Jena, *12*, 1925, 460). The reported and personally observed sizes of such units show that the extreme limits are linked by a complete series of transitions.

Illustrations: Buder, *loc. cit.*, Pl. XXIV, fig. 1–5; Perfiliev, Jour. Microbiol. (Russian), *1*, 1914, 213, fig. 1–5.

Genus VI. Cylindrogloea *Perfiliev.*

(Jour. Microbiol. (Russian), *1*, 1914, 223.) From Latin *cylindrus*, cylinder and Greek *gloios*, a glutinous substance.

Green sulfur bacteria, consisting of small ovoid to rod-shaped cells, growing in association with a filamentous, colorless, central bacterium, thus forming colonies of a cylindrical shape. Non-motile. The green component contains a chlorophyllous pigment different from the common chlorophylls of green plants and from bacteriochlorophyll. Capable of photosynthesis in the presence of hydrogen sulfide, without depositing sulfur globules in the cells.

The type species is *Cylindrogloea bacterifera* Perfiliev.

1. **Cylindrogloea bacterifera** Perfiliev. (Jour. Microbiol. (Russian), *1*, 1914, 223.) From Latin *bacter*, rod and *fero*, to bear.

Individual green components ovoid to rod-shaped, about 0.5 to 1 by 2 to 4 microns, very similar to those of the complex *Chlorobacterium symbioticum* and *Chlorochromatium aggregatum* with which they may well be identical. The central filamentous bacterium is embedded in a slime capsule of considerable dimensions. This, in turn, is surrounded by a layer of green bacteria, usually one cell thick. The green organisms may form a very dense outer covering, or they may be more sparsely distributed over the mucus capsule. The entire unit is again surrounded by a sizeable slime zone. Aggregates measure about 7 to 8 microns in width, and up to 50 microns in length; they are non-motile. Both components appear to be non-spore-forming.

Habitat: Mud and stagnant water containing rather high concentrations of hydrogen sulfide and exposed to light.

Illustration: Perfiliev, *loc. cit.*, 213, fig. 6–11.

Perfiliev rightly emphasizes, as Buder had done for *Chloronium mirabile*, the provisional nature of thus using a generic designation for an apparently stable complex composed of two different organisms. It remains possible that the last three genera of symbiotic entities represent fortuitous combinations whose occurrence is conditioned by environmental factors. If so, the generic terminology would be devoid of any taxonomic significance, and the green bacteria should be relegated to more appropriate genera. Indications suggestive of this state of affairs can be found in the literature; for example in Utermöhl's observation (Archiv f. Hydrobiol., Suppl. *5*, 1925, 279) that the complex *Chlorochromatium aggregatum* may, especially in the presence of oxygen, disintegrate, whereupon the green constituents appear as small *Pelodictyon aggregatum* (*Schmidlea luteola*) colonies.

ORDER II. ACTINOMYCETALES BUCHANAN.

(Jour. Bact., *2*, 1917, 162.)

Organisms forming elongated cells which have a definite tendency to branch. These hyphae do not exceed 1.5 microns and are mostly about 1 micron or less in diameter. In the *Mycobacteriaceae* the mycelium is rudimentary or absent; no spores are formed; the cells are acid-fast. The *Actinomycetaceae* and *Streptomycetaceae* usually produce a characteristic branching mycelium and multiply by means of special spores, oidiospores or conidia. Special spores are formed by fragmentation of the plasma within straight or spiral-shaped spore-bearing hyphae; the oidiospores are formed by segmentation, or by transverse division of hyphae, similar to the formation of oidia among the true fungi; the conidia are produced singly, at the end of simple or branching conidiophores. They grow readily on artificial media and form well-developed colonies. The surface of the colony, especially in the *Actinomycetaceae* and *Streptomycetaceae*, may become covered with an aerial mycelium. Some form colorless or white colonies, whereas others form a variety of pigments. Some species are partially acid-fast. In relation to temperature, most are mesophilic, while some are thermophilic. Certain forms are capable of growing at low oxygen tension. The Order as a whole is composed of saprophytic species, but also includes species that are parasitic and sometimes pathogenic on both animals and plants.

Key to the families of order **Actinomycetales.**

I. Mycelium rudimentary or absent, no spores formed. Acid-fast.

Family I. *Mycobacteriaceae*, p. 875.

II. True mycelium produced.

A. Vegetative mycelium divides by segmentation into bacillary or coccoid elements. Some species partially acid-fast.

Family II. *Actinomycetaceae*, p. 892.

B. Vegetative mycelium normally remains undivided.

Family III. *Streptomycetaceae*, p. 929.

Among the recent systems of classification of this order it is sufficient to mention the following: Baldacci (Mycopath., *2*, 1939, 84) divided the order *Actinomycetales* into two families: (a) *Mycobacteriaceae* Chester with two subfamilies, *Leptotrichioideae* Baldacci and *Proactinomycoideae* Baldacci, each with five genera, and (b) *Actinomycetaceae* Buchanan, with two genera, *Micromonospora* and *Actinomyces*. Krassilnikov (Ray fungi and related organisms, Izd. Akad. Nauk, Moskow, 1938) divided the order into (a) *Actinomycetaceae*, with four genera, *Actinomyces*, *Proactinomyces*, *Mycobacterium* and *Mycococcus*, and (b) *Micromonosporaceae*, with one genus, *Micromonospora*. Waksman (Jour. Bact., *39*, 1940, 549) divided the order into four families: *Mycobacteriaceae*, *Proactinomycetaceae*, *Actinomycetaceae* and *Micromonosporaceae*.

FAMILY I. MYCOBACTERIACEAE CHESTER.*

(Chester, Man. Determ. Bact., 1901, 349; *Proactinomycetaceae* Lehmann and Haag, in Lehmann and Neumann, Bákt. Diag., 7 Aufl., *2*, 1927, 674.)

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* Completely revised by Prof. G. B. Reed, Queens University, Kingston, Ontario, Canada, December, 1938; minor revisions, December, 1944; with a complete revision of *Mycobacterium leprae* and *M. lepraemurium* by Dr. John H. Hanks, Leonard Wood Memorial, American Leprosy Foundation, New York, N. Y.

Slender filaments, straight or slightly curved rods, frequently irregular in form with only slight and occasional branching. Often stain unevenly, i.e., show variations in staining reaction within the cell (beading). No conidia. Non-motile. Aerobic. Gram-positive. Acid-fast.† Pathogenic species grow slowly (several weeks); those from soil, water and vegetation more rapidly (several days).

There is a single genus *Mycobacterium* Lehmann and Neumann.

Genus I. **Mycobacterium** *Lehmann and Neumann.*

(*Coccothrix* Lutz, Zur Morphologie des Mikroorganismus der Lepra. Dermatologische Studien, Heft 1, 1886, 22; *Schlerothrix* Metschnikoff, Arch. f. path. Anat. u. Physiol., *113*, 1888, 70; Lehmann and Neumann, Bakt. Diag., 1 Aufl., *2*, 1896, 108; *Mycomonas* Orla-Jensen, Cent. f. Bakt., II Abt., *22*, 1909, 329; *Eumyces* Battaglia, Soc. Internaz. Microbiol. Boll. Sez. Ital., *10*, 1938, 166.) From Greek *myces*, fungus and *bacterium*, a little rod.

Characters as for the family.

The type species is *Mycobacterium tuberculosis* (Schroeter) Lehmann and Neumann.

Key to the species of genus **Mycobacterium.**

I. Parasites in warm-blooded animals; grow slowly on all media.
  A. Grow slowly on glycerol agar in atmospheric air; experimentally infect guinea pigs and fowls.
    1. Experimentally produces generalized tuberculosis in guinea pigs but not in rabbits and fowls. Growth enhanced by the addition of glycerol to most media. Generally pale yellow to orange pigmentation on serum media.
      1a. *Mycobacterium tuberculosis* var. *hominis.*
    2. Experimentally produces generalized tuberculosis in guinea pigs and rabbits but not in fowls. Growth not enhanced by addition of glycerol to media. Never pigmented.
      1b. *Mycobacterium tuberculosis* var. *bovis.*
    3. Experimentally produces generalized tuberculosis in fowls and rabbits but not in guinea pigs.
      2. *Mycobacterium avium.*
  B. Grows in primary culture on glycerol agar only when extracts of, or heat-killed acid-fast bacilli are added. Experimentally fails to infect guinea pigs or fowls.
      3. *Mycobacterium paratuberculosis.*
  C. Have not been grown on culture media thus far devised. Experimentally fail to infect guinea pigs or fowls.
    1. Has not experimentally been transmitted to any animal species.
      4. *Mycobacterium leprae.*
    2. Occurs in wild rats, and can be experimentally transmitted to rats and some strains of mice.
      5. *Mycobacterium lepraemurium.*

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† Most acid-fast bacteria treated with carbol-auramin and decolorized with NaCl-HCl-alcohol show fluorescence under the microscope when they are radiated by long wavelength ultraviolet light (Haitinger, Fluorescenz-mikroskopie, Leipzig, 1938, 108 pp.; Ellinger, Biol. Revs., *15*, 1940, 323–350; Richards, Jour. Bact., *44*, 1942, 721).

For a discussion of the influence of environment on acid-fastness, see Salle and Moser, Internat. Jour. Leprosy, *5*, 1937, 163.

II. Saprophytes or parasites on cold-blooded animals; grow rapidly on most media.
  A. Fail to survive 60°C for 1 hour.
    1. Fail to grow at 47°C.
      a. Unable to utilize sorbitol.
        6. *Mycobacterium piscium.*
        7. *Mycobacterium marinum.*
        8. *Mycobacterium ranae.*
        9. *Mycobacterium thamnopheos.*
      aa. Utilize sorbitol.
        10. *Mycobacterium friedmannii.*
        11. *Mycobacterium spp.*
    2. Grows at 47°C.
        12. *Mycobacterium lacticola.*
  B. Survives 60°C for 1 hour; grows at 47°C.
        13. *Mycobacterium phlei.*

1. **Mycobacterium tuberculosis** (Schroeter) Lehmann and Neumann. (Tuberkelbacillen, Koch, Mitteil. a.d. kaiserlich. Gesundheitsamte, *2*, 1884, 6; *Bacillus tuberculosis* Schroeter, in Cohn, Kryptogamen Flora v. Schlesien, *3*, 1886, 164; *Bacillus tuberculosis* Flügge, Die Mikroorganismen, 2 Aufl., 1886, 208; *Coccothrix tuberculosis* Lutz, Dermatol. Studien, *1*, 1886, 22; *Sclerothrix kochii* Metchnikoff, Arch. f. path. Anat. u. Physiol., *113*, 1888, 70; *Bacterium tuberculosis* Migula, in Engler and Prantl, Die natürlichen Pflanzenfamilien, I Abt., 1a, 1895, 23; Lehmann and Neumann, Bakt. Diag., 1 Aufl., *2*, 1896, 363; *Bacillus kochii*, quoted from Lehmann and Neumann, *idem; Discomyces tuberculosus* (sic), quoted from Neveu-Lemaire, Précis de Parasitol. Humaine, 5th ed., 1921, 25; *Sclerothrix tuberculosis* Vuillemin, Encyclopédie Mycologique, Paris, *2*, 1931, 134; *Eumyces tuberculosis* Battaglia, Soc. Internaz. Microbiol. Boll. Sez. Ital., *10*, 1938, 166.) From M. L. *tuberculosis*, tuberculosis.

Two varieties of this species are commonly recognized, the human and the bovine.

1a. *Mycobacterium tuberculosis* var. *hominis* Lehmann and Neumann. (Human tubercle bacilli, Th. Smith, Trans. Assoc. Am. Phys., *11*, 1896, 75; *Mycobacterium tuberculosis* typus *humanus* Lehmann and Neumann, Bakt. Diag., 4 Aufl., *2*, 1907, 550.) From Latin *hominis*, of man.

Common name: Human tubercle bacillus.

Description from Koch (*loc. cit.*) and Topley and Wilson (Princip. of Bact. and Immun., London, 2nd ed., 1936, 315).

Rods, ranging in size from 0.3 to 0.6 by 0.5 to 4.0 microns, straight or slightly curved, occurring singly and in occasional threads. Sometimes swollen, clavate or even branched. Stain uniformly or irregularly, showing banded or beaded forms. Acid-fast and acid-alcohol-fast. Gram-positive. Growth in all media is slow, requiring several weeks for development.

This bacterium contains mycolic acid (Stodola, Lesuk, and Anderson, Jour. Biol. Chem., *126*, 1938, 505–513). The acid-fast mycolic acid combines more firmly with carbol-auramin than with carbol-fuchsin and this apparently accounts for the increased sensitivity of fluorescence microscopy for this bacterium (Richards, Science, *93*, 1941, 190; Richards, Kline, and Leach, Amer. Rev. Tuberc., *44*, 1941, 255–266).

Nutrient agar: No growth.

Glycerol agar colonies: Raised, thick, cream-colored, with a nodular or wrinkled surface and irregular thin margin.

Glycerol agar slant: After 4 weeks, raised, thick, confluent, cream-colored growth.

Nutrient broth: No growth.

Glycerol broth: After 8 weeks, thick, white or cream-colored, wrinkled pellicle extending up the sides of the flask, no turbidity; granular or scaly deposit.

Dorset's egg slants: After 4 weeks, rather sparse, discrete or confluent, slightly raised, grayish-yellow growth with finely granular surface.

Glycerol egg slants: After 4 weeks, luxuriant, raised, confluent, gray to yellow growth, with granular surface, generally with nodular heaped-up areas.

Coagulated beef serum: After 4 weeks, thin, effuse, confluent, gray to yellow growth, with a very fine granular surface.

Glycerol beef serum: After 4 weeks, luxuriant, thick, raised, confluent, yellow to orange-yellow growth, with coarsely granular surface, generally with irregularly heaped-up areas.

Litmus milk: Growth, but no change in the milk.

Glycerol potato: After 4 weeks, luxuriant, raised, confluent, cream-colored growth with a nodular or warty surface.

Carbohydrates: Glucose, fructose, arabinose and galactose are utilized; sucrose and lactose not utilized (Merrill, Jour. Bact., *20*, 1930, 235, based on the examination of one strain).

Optimum temperature 37°C.

Optimum pH 7.4 to 8.0 (Ishimori, Ztschr. f. Hyg., *102*, 1924, 329); pH 6.0 to 6.5 (Dernby and Näslund, Biochem. Zeit., *132*, 1922, 392).

Pathogenicity: Produces tuberculosis in man, monkey, dog and parrot. Experimentally, it is highly pathogenic for guinea pigs but not for rabbits, cats, goats, oxen or domestic fowls.

Intermediate mammalian types: Griffith (Lancet, *1*, 1916–17, 721; Jour. Path. and Bact., *21*, 1924, 54) has found aberrant types particularly in skin lesions of both man and ox, which are in certain characteristics intermediate between the human and the bovine varieties. He finds no evidence, however, that the one variety may change into the other.

Variation: Variation in colony structure of the two mammalian varieties, comparable with that in other species, has been described by several authors, as Petroff et al. (Jour. Exp. Med., *60*, 1934, 515), Birkhaug (Ann. Inst. Past., *57*, 1933, 428), Kahn et al. (Jour. Bact., *25*, 1933, 157), Uhlenhuth and Sieffert (Zeit. Immun., *59*, 1930, 187), Reed and Rice (Canad. Jour. Res., *5*, 1931, 111), Smithburn (Jour. Exp. Med., *63*, 1936, 95) and Shaffer (Jour. Path. and Bact., *40*, 1935, 107). Several of these authors have found associated variation in cell structure and in virulence though Boquet (Compt. rend. Soc. Biol. Paris, *103*, 1930, 290), Birkhaug (Ann. Inst. Past., *49*, 1932, 630), and others, have failed to find differences in virulence. Reed and Rice (Jour. Immunol., *23*, 1932, 385) found the S form to contain an antigenic substance lacking in the R form.

Antigenic structure: By agglutination, absorption of agglutinins and complement fixation a distinction may be made between the mammalian varieties and *Mycobacterium avium*, but it has been impossible to distinguish, by these means, between the two mammalian varieties (Tullock et al., Tubercle, *6*, Oct.–Dec., 1924, 18, 57 and 105; Wilson, Jour. Path. and Bact., *28*, 1925, 69; Griffith, Tubercle, *6*, May, 1925, 417; Rice and Reed, Jour. Immunol., *23*, 1932, 385; Kauffman, Ztschr. f. Hyg., *114*, 1932, 121). Tuberculins prepared from the human and the bovine varieties are ordinarily indistinguishable in their action but Lewis and Seibert (Jour. Immunol., *20*, 1931, 201) detected a difference by cross anaphylactic reactions.

Distinctive characters: Tubercle bacilli pathogenic for guinea pigs and rabbits, not for fowls. *Mycobacterium tuberculosis* var. *hominis* produces generalized tuberculosis in guinea pigs but not in rabbits. *Mycobacterium tuberculosis* var. *bovis* produces generalized disease in both guinea pigs and rabbits. Growth of the human variety is enhanced by the addition of glycerol to most media. The growth of the bovine variety is not enhanced by the addition

of glycerol. The human variety generally develops yellow to red pigment on serum media, while the bovine variety never produces pigment. Antigenically the two varieties are not distinguishable.

Source: From tuberculous lesions in man.

Habitat: The cause of tuberculosis in man. Transmissible to rabbits and guinea pigs.

1b. *Mycobacterium tuberculosis* var. *bovis* Lehmann and Neumann. (Bovine tubercle bacilli, Th. Smith, Trans. Assoc. Am. Phys., *11*, 1896, 75; *13*, 1898, 417; Jour. Exp. Med., *3*, 1898, 451; *Mycobacterium tuberculosis* typus *bovinus* Lehmann and Neumann, Bakt. Diag., 4 Aufl., *2*, 1907, 550.) From Latin *bovis*, of the ox.

Common name: Bovine tubercle bacillus.

Description from Th. Smith (*loc. cit.*) and Topley and Wilson (Princip. of Bact. and Immun., 2nd ed., 1936, 315).

Rods which are shorter and plumper than the human type. Range in size from 1.0 to 1.5 microns. Very short forms are frequently intermixed with somewhat larger forms. Stain regularly or irregularly. Acid-fast and acid-alcohol-fast. Gram-positive. Less easily cultivated than the human variety.

Nutrient agar: No growth.

Glycerol agar colonies: Small, irregular, with granular surface, no pigment.

Glycerol agar slant: After 4 weeks, thin, granular or effuse, confluent growth.

Nutrient broth: No growth.

Glycerol broth: After 8 weeks, thin grayish-white film, slightly nodular, no turbidity. Slight granular deposit.

Dorset's egg slants: After 4 weeks, similar to var. *hominis* but generally poorer growth and no pigmentation.

Glycerol egg slants: After 4 weeks, similar to Dorset's egg slants.

Coagulated beef serum: After 4 weeks, thin, effuse, confluent, white to gray growth with very fine granular surface. Generally less luxuriant than in the human variety.

Glycerol beef serum: After 4 weeks, similar to plain beef serum.

Glycerol potato: After 4 weeks, thin, effuse, grayish growth.

Litmus milk: Growth, but no change in the milk.

Optimum temperature 37°C.

Optimum pH 5.8 to 6.9 (Ishimori, Ztschr. f. Hyg., *102*, 1924, 329); 6.0 to 6.5 (Dernby and Näslund, Biochem. Zeit., *132*, 1922, 392).

Pathogenicity: Produces tuberculosis in ox, man, monkey, goat, sheep, pig, cat, parrot, cockatoo and possibly some birds of prey. Experimentally, it is highly pathogenic for rabbit and guinea pig, slightly pathogenic for dog, horse, rat and mouse; not pathogenic for fowls.

Variation: See *Mycobacterium tuberculosis* var. *hominis*.

Antigenic structure: See *Mycobacterium tuberculosis* var. *hominis*.

Distinctive characters: See *Mycobacterium tuberculosis* var. *hominis*.

Source: From tubercles in cattle.

Habitat: The cause of tuberculosis in cattle. Transmissible to man and domestic animals. More highly pathogenic for animals than the human type.

2. **Mycobacterium avium** Chester. (Tuberculose des oiseaux, Strauss and Gamaléia, Arch. Méd. exp. et Anat. path., 1891; Bacillus der Hühnertuberculose, Maffucci, Ztschr. f. Hygiene, *11*, 1892, 449; *Bacillus tuberculosis gallinarum* Sternberg, Man. of Bact., 1893, 392; *Mycobacterium tuberculosis avium* Lehmann and Neumann, Bakt. Diag., 1 Aufl., *1*, 1896, 370; *Bacillus tuberculosis avium* Kruse, in Flügge, Die Mikroorganismen, 3 Aufl., *2*, 1896, 506; *Mycobacterium avium* Chester, Manual Determ. Bact., 1901, 357; *Mycobacterium tuberculosis* typus *gallinaceus* Lehmann and Neumann, Bakt. Diag., 4 Aufl., *2*, 1907, 553.) From Latin *avis*, bird.

Common name: Avian tubercle bacillus.

Description from Strauss and Gamaléia (*loc. cit.*) and Topley and Wilson (Princip. of Bact. and Immun., 2nd ed., 1936, 315).

Rods resembling those of the bovine type of tubercle organism.

Nutrient agar: After 4 weeks, slight growth, effuse, translucent with fine granular surface.

Glycerol agar colonies: After 3 to 4 weeks, raised, regular, hemispherical, creamy or white colonies.

Nutrient broth: After 4 weeks, very slight viscous to granular bottom growth, no pellicle, no turbidity.

Glycerol broth: After 4 weeks, diffuse, turbid growth with a viscous to granular deposit.

Dorset's egg slants: After 4 weeks, confluent, slightly raised growth, with smooth regular surface.

Glycerol egg slants: After 4 weeks, luxuriant, raised, confluent, creamy to yellow growth with perfectly smooth surface.

Coagulated beef serum: After 4 weeks, thin, effuse, grayish-yellow growth with smooth surface.

Glycerol beef serum: After 4 weeks, luxuriant, raised, confluent, yellow to orange-yellow or occasionally pale pink growth, with a smooth glistening surface.

Glycerol potato: After 4 weeks, luxuriant, raised, confluent, with smooth to nodular surface.

Litmus milk: Growth, but no change in the milk.

Carbohydrates: Fructose, arabinose and sucrose are utilized, glucose is slightly utilized, galactose and lactose are not utilized (Merrill, Jour. Bact., *20*, 1930, 235, based on the examination of one strain).

Optimum temperature 40°C; range 30° to 44°C (Bynoe, Thesis, McGill University, Montreal, 1931).

Optimum pH 6.8 to 7.3 (Bynoe, *loc. cit.*).

Pathogenicity: Produces tuberculosis in domestic fowls and other birds. In pigs it produces localized and sometimes disseminated disease. Experimentally in the rabbit, guinea pig, rat and mouse it may proliferate without producing macroscopic tubercles—tuberculosis of the Yersin type. Man, ox, goat, cat, horse, dog and monkey are not infected.

Variation: Winn and Petroff (Jour. Exp. Med., *57*, 1933, 239), Kahn and Schwartzkopf (Jour. Bact., *25*, 1933, 157), Birkhaug (Ann. Inst. Pasteur, *54*, 1935, 19), Reed and Rice (Canad. Jour. Res., *5*, 1931, 111) and others, have shown variation to follow the course described for many species. Winn and Petroff have separated four colonial types: smooth, flat smooth, rough, deep yellow smooth. These also differ in chemical and physical properties. The smooth form exhibited the greatest degree of virulence, the flat smooth a lower virulence, while the chromogenic smooth and the rough were relatively benign. Some authors have failed to demonstrate this difference in virulence. The above description applies primarily to the smooth form.

Antigenic structure: By agglutination, absorption of agglutinins and complement fixation *Mycobacterium avium* may be distinguished from other members of the genus (Tullock et al., Tubercle, *6*, 1924, 18, 57 and 105; Wilson, Jour. Path. and Bact., *28*, 1925, 69; Mudd, Proc. Soc. Exp. Biol. and Med., *23*, 1925, 569, and others). Furth (Jour. Immunol., *12*, 1926, 273) and Shaffer (Jour. Path. and Bact., *40*, 1935, 107) on this basis divided *Mycobacterium avium* into 1 or 2 subgroups.

Distinctive characters: Tubercle bacilli pathogenic for fowls, not for guinea pigs or rabbits. Culturally distinguished from the mammalian types by the absence of pellicle formation in fluid media and the habit of growth on most solid media. Antigenically distinguished from other species.

Source: From tubercles in fowls, widely distributed as the causal agent of tuberculosis in birds and less frequently in pigs.

Habitat: The cause of tuberculosis in chickens. Transmissible to pigeon, other birds, mouse, rabbit and pig.

3. **Mycobacterium paratuberculosis** Bergey et al. (Darmtuberculose bacillen, Johne and Frothingham, Deutsch. Ztschr. Tiermed., *21*, 1895, 438; Pseudotuberkulose bacillen, Bang, Berl. tierärztl. Wchnschr., 1906, 759; Bacillus of Johne's Disease, M'Fadyean, Jour. Comp. Path., *20*, 1907, 48; Twort, Proc. Roy. Soc., B, *83*, 1910, 156; Bergey et al., Manual, 1st ed., 1923, 374.) From M. L. *paratuberculosis*, of the disease paratuberculosis.

Common name: Johne's bacillus.

The organism from a similar disease in sheep is probably identical though more difficult to cultivate (Dunkin and Balfour-Jones, Jour. Comp. Path., *48*, 1935, 236).

Description from M'Fadyean (*loc. cit.*) and Twort and Ingram (A Monograph on Johne's Disease, London, 1913).

Plump rods, 1.0 to 2.0 microns in length, staining uniformly, but occasionally the longer forms show alternately stained and unstained segments. Non-motile. Acid-fast.

The organism is difficult to cultivate and, in primary cultures, has only been grown in media containing dead tubercle bacilli or other dead acid-fast bacteria (Boquet, Ann. Inst. Pasteur, *37*, 1928, 495). In a few instances cultures have been acclimatized to a synthetic medium free from added dead bacteria (Dunkin, Jour. Comp. Path. and Therap., *46*, 1933, 159; Watson, Canad. Pub. Health Jour., *26*, 1935, 268).

Colonies on glycerol agar containing heat-killed *Mycobacterium phlei:* After 4 to 6 weeks, just distinguishable, dull-white, raised, circular colonies.

Colonies on Dorset's glycerol egg containing heat-killed *Mycobacterium phlei:* After 4 to 6 weeks, minute, dull-white, raised, circular, with a thin, slightly irregular margin. Older colonies become more raised, radially striated or irregularly folded and dull yellowish-white.

Dorset's glycerol egg containing sheep's brain and heat-killed *Mycobacterium phlei:* Growth slightly more luxuriant.

Glycerol broth containing heat-killed *Mycobacterium phlei:* Thin surface pellicle which later becomes thickened and folded.

Dorset's synthetic fluid containing heat-killed *Mycobacterium phlei:* As on glycerol broth with *Mycobacterium phlei.*

Pathogenicity: Produces Johne's disease, chronic diarrhea, in cattle and sheep. Experimentally it produces a similar disease in bovine animals, sheep and goats. Guinea pigs, rabbits, rats and mice are not infected. Very large doses in laboratory animals produce slight nodular lesions comparable with those produced by *Mycobacterium phlei.*

Antigenic structure: Johnin, prepared as tuberculin, gives positive reactions in cattle with Johne's disease. According to M'Fadyean et al. (Jour. Comp. Path. and Therap., *29*, 1916, 62) tuberculous animals may also give a reaction. Plumb (Den Kong. Vet. Landbohøjskole Årssk., 1925, 63) has shown that a reaction may be produced in animals sensitized to avian tuberculin and that avian tuberculin causes a reaction in some animals infected with Johne's bacillus.

Distinctive characters: A small acid-fast bacillus producing characteristic lesions in cattle and growing only in the presence of dead acid-fast bacilli.

Source: From the intestinal mucous membrane of cattle suffering from chronic diarrhea. Apparently an obligate parasite.

Habitat: The cause of Johne's disease, a chronic diarrhea in cattle. The bacteria are found in the intestinal mucosa. Not pathogenic for guinea pigs or rabbits.

4. **Mycobacterium leprae** (Armauer-Hansen) Lehmann and Neumann. (*Bacillus leprae* Armauer-Hansen, Norsk. Mag. Laegevidensk., *9*, 1874, 1; Arch. f. path. Anat. u. Physiol., *79*, 1879,

32; Nord. Med. Ark., *12*, 1880, 1; Quart. Jour. Micro. Sci., *20*, 1880, 92; *Coccothrix leprae* Lutz, Dermatol. Stud. *1*, 1886, quoted from DeToni and Trevisan, in Saccardo, Sylloge Fungorum, *8*, 1889, 944; Lehmann and Neumann, Bakt. Diag., 1 Aufl., *2*, 1896, 372; *Discomyces leprae* Neveu-Lemaire, Précis Parasit. Hum., 5th ed., 1921, 27; *Sclerothrix leprae* Vuillemin, Encyclopédie Mycologique, Paris, *1*, 1921, 135; *Mycobacterium leprae hominus* Lowe, Internat. Jour. Leprosy, *5*, 1937, 312.) From Greek *lepra*, leprosy.

Common name: Leprosy bacillus.

Armauer-Hansen (*loc. cit.*) was the first to observe the bacilli in the tissues of lepers. The disease is now known as Hansen's disease. The bacilli occur in enormous numbers in lepromatous (nodular) cases of the disease and sparsely in the neural form. The present bacteriological means of identification depend on: (a) acid-fast staining, and (b) failure of the organism to grow in bacteriological media or in laboratory animals. Heated suspensions of the bacilli (obtained from nodules) produce a positive lepromin reaction in 75 to 97 per cent of normal persons and of neural cases of leprosy, but usually produce no reaction in lepromatous individuals (Mitsuda: See Hayashi, Int. Jour. Leprosy, *1*, 1933, 31–38). The failure of lepromatous persons to respond to injected leprosy bacilli constitutes a fundamental criterion for testing the validity of microorganisms such as other acid-fast or diphtheroid cultures which can at times be recovered from leprous tissues by inoculation of bacteriological media.

Many organisms have been isolated from leprous tissues, some of which are acid-fast and have been styled *Mycobacterium leprae*. The strains which have been adequately studied have proven to fall into the saprophytic groups (see No. 11, *Mycobacterium spp.*) Hanks (Int. Jour. Leprosy, *9*, 1941, 275–298) found that acid-fast cultures of this type, as well as the diphtheroids which also have repeatedly been isolated from leprosy, were recoverable only from lesions located proximally with respect to open ulcers in the skin.

Description of organisms seen in leprosy tissue from Armauer-Hansen (*loc. cit.*) and Topley and Wilson (Princip. Bact. and Immun., 2nd ed., 1936, 316).

Rods: 0.3 to 0.5 by 1 to 8 microns, with parallel sides and rounded ends, staining evenly or at times beaded. When numerous, as from lepromatous cases, they are generally arranged in clumps, rounded masses or in groups of bacilli side by side. Strongly acid-fast. Gram-positive.

Pathogenicity: The communicability of leprosy from man to man is accepted (Rogers and Muir, Leprosy, 2nd ed., Baltimore, 1940, 260 pp.). Experimental transmission to humans or to animals has not been successful.

Source: Human leprous lesions. In the lepromatous form of the disease bacilli are so abundant as to produce stuffed-cell granulomas; in the tuberculoid and neutral lesions they are rare.

Habitat: Obligate parasite in man. Confined largely to the skin (especially to convex and exposed surfaces) and to peripheral nerves. The microorganisms probably do not grow in the internal organs.

5. **Mycobacteriun lepraemurium** Marchoux and Sorel. (Bacillus der Rattenlepra, Stefansky, Cent. f. Bakt., I Abt., Orig., *33*, 1903, 481; *Mycobacterium leprae murium* Marchoux and Sorel, Ann. Inst. Past., *26*, 1912, 700; *Bacillus leprae murium* Muir and Henderson, Indian Jour. Med. Res., *15*, 1927, 15.)

Mycobacterium pulviforme Marchoux (Ann. Derm., 1921, No. 21 and Ann. Inst. Past., *37*, 1923, 348) from leprosy-like lesions in a man from Hayti is thought by the author to be identical with *Mycobacterium lepraemurium*.

Common name: Rat leprosy bacillus.

Rods: 3.0 to 5.0 microns in length with slightly rounded ends. When stained, often show irregular appearance. Strongly acid-fast. Gram-positive.

Like the human leprosy bacillus, this organism has not been cultivated in vitro; but can be passed experimentally through rats and some strains of mice.

Distinctive features: The heat-killed bacilli produce lepromin reactions in lepratomous humans. The bacilli from lesions are not bound together in clumps, rounded masses and palisades as in human lesions. For further details see review by Lowe (Internat. Jour. Leprosy, *5*, 1937, 310 and 463).

Source: An endemic disease of rats in various parts of the world, having been found in Odessa, Berlin, London, New South Wales, Hawaii, San Francisco and elsewhere.

Habitat: The natural disease occurs chiefly in the skin and lymph nodes, causing induration, alopecia (loss of hair) and eventually ulceration.

6. **Mycobacterium piscium** Bergey et al. (*Bacillus tuberculosis piscium* Dubard, Bull. acad. de méd., 3 sér., *38*, 1897, 580; Bataillon, Dubard and Terre, Compt. rend. Soc. Biol., *4*, sér. 10, 1897, 446; Bergey et al., Manual, 1st ed., 1923, 375.) From Latin *piscis*, fish.

Description from Bataillon et al. (*loc. cit.*) and Aronson (Jour. Inf. Dis., *39*, 1926, 319).

Slender rods, occurring singly and in threads, occasionally showing branching. Acid-fast. Non-motile. Gram-positive.

Agar colonies: Small, circular, white, moist, with lobate margin and fine granular surface.

Agar slant: Scant, white, moist, cream-like.

Glycerol agar colonies: Thin, flat, smooth, glistening, yellow.

Dorset's egg medium: Flat, smooth, moist, greenish.

Broth: Thin pellicle, with flocculent sediment.

Litmus milk: Thickened. No coagulation. Slightly alkaline.

Potato: White, warty, butyrous colonies.

Carbohydrates: Utilizes glucose and fructose but not sucrose, lactose, arabinose or galactose (Merrill, Jour. Bact., *20*, 1930, 235, based on examination of one strain).

Antigenic structure: By agglutination and complement fixation (Mudd, Proc. Exp. Biol. and Med., *23*, 1925, 569; and Furth, Jour. Immunol., *12*, 1926, 286) *Mycobacterium piscium* has been distinguished from *Mycobacterium friedmannii*, *Mycobacterium ranae* and probably *Mycobacterium marinum*. From the limited number of cultures examined it is not evident whether this is due to species or strain specificity.

Pathogenicity: Experimentally produces tubercles in carp, frog and lizard, but not pathogenic for rabbit, guinea pig or birds (Dubard, Rev. de la Tuberc., *6*, 1898, 13). Not pathogenic for salt water fish except eels (Betegh, Cent. f. Bakt., I Abt., Orig., *53*, 1910, 374; *54*, 1910, 211).

Distinctive characters: *Mycobacterium piscium*, *Mycobacterium marinum*, *Mycobacterium ranae*, *Mycobacterium thamnopheos* and *Mycobacterium friedmannii* constitute a closely related group—possibly one species. They differ from other members of the genus in their pathogenicity for cold-blooded animals, their failure to survive 60°C for an hour, their failure to grow at 47°C and their inability to utilize sorbitol.

Mycobacterium marinum is distinguished by its diffuse growth in broth, acid production in milk and deep yellow to orange pigmentation on most media. The other species grow in broth as a pellicle and render milk alkaline. *Mycobacterium piscium*, *Mycobacterium ranae*, *Mycobacterium thamnopheos* and *Mycobacterium friedmannii* may be distinguished from each other by their habit of growth on solid media. But relatively few cultures have been studied

and the reports in certain important respects are conflicting, especially concerning pigmentation and utilization of carbohydrates. Aronson, Mudd and Furth found them to differ antigenically, but too few cultures were used to distinguish between species and strain specificity.

Source: From tubercles in carp.

Habitat: The cause of nodule and tumor-like formations in carp (*Ciprinus carpio*). Infectious for carp, frogs, lizards. Not infectious for guinea pigs and pigeons.

7. **Mycobacterium marinum** Aronson. (Jour. Inf. Dis., *39*, 1926, 315.) From Latin *marinus*, marine.

Description from Aronson (*loc. cit.*).

In lesions, short, thick, uniformly staining organisms are seen frequently occurring in clumps, while long, thin, beaded or barred rods are scattered more discretely. In cultures the organisms have the same appearance. Non-motile. Acid-fast and acid-alcohol-fast. Gram-positive.

Agar slant (slightly acid): In five to seven days, moist, glistening, elevated colonies, becoming lemon-yellow.

Gelatin: Not liquefied.

Agar colonies: In 5 to 7 days, smooth, moist, slimy, lemon-yellow, later orange-colored.

Glycerol agar colonies: In 14 to 18 days, grayish-white, moist, elevated with irregular margins. Old growths lemon-yellow and still later orange-colored.

Dorset's and Petroff's egg media: Similar to growth on glycerol agar but more luxuriant.

Broth and glycerol broth: Growth is diffuse, no pellicle formed.

Litmus milk: Acidified and coagulated.

Indole not formed.

Nitrites not produced from nitrates.

Carbohydrates: Utilizes arabinose and fructose, fails to utilize sorbitol and galactose (Gordon, Jour. Bact., *34*, 1937, 617).

Aerobic, facultative.

Optimum temperature 18° to 20°C. Fails to survive 60°C for 1 hour, fails to grow at 47°C (Gordon, Jour. Bact., *34*, 1937, 617).

Pathogenicity: Experimentally infects salt water fish, goldfish, frogs, mice and pigeons, but not rabbits or guinea pigs.

Antigenic structure: By agglutination and complement fixation distinguished from *Mycobacterium ranae*, *Mycobacterium friedmannii*, and probably *Mycobacterium piscium* (Mudd, Proc. Soc. Exp. Biol. and Med., *23*, 1925, 569; Furth, Jour. Immunol., *12*, 1926, 286). See *Mycobacterium piscium*.

Distinctive characters: See *Mycobacterium piscium*.

Source: From areas of focal necrosis of the liver of sergeant majors (*Abudefduf mauritii*), croakers (*Micropogon undulatus*) and sea bass (*Centropristes striatus*).

Habitat: Causes spontaneous tuberculosis in salt water fish.

8. **Mycobacterium ranae** (Küster) Bergey et al. (Küster, Münch. med. Wchnschr., *52*, 1905, 57; Bergey et al., Manual, 1st ed., 1923, 374.) From Latin *rana*, frog.

Description from Küster (*loc. cit.*), Bynoe (Thesis, McGill University, Montreal, 1931) and Aronson (Jour. Inf. Dis., *44*, 1929, 222).

Slender rods, 0.3 to 0.5 by 2 to 8 microns, smaller in old cultures. Uniformly acid-fast in cultures 2 weeks old or older. In younger cultures the staining is irregular, many organisms are not acid-fast. Non-motile. Gram-positive.

Gelatin stab: No liquefaction.

Agar colonies: Irregular, raised colonies, 1 to 3 mm in diameter with moist glistening surface, later becoming coarsely granular.

Agar slant: Thick, spreading, glistening. In old cultures dry and scaly. Putrid odor. Grayish-white.

Glycerol agar colonies: Similar to gelatin colonies but slightly creamy and becoming dry and wrinkled in old cultures.

Dorset's egg medium: Spreading, raised, glistening, later wrinkled.

Loeffler's medium: Similar to Dorset's egg medium, white to buff-colored.

Litmus milk: Becomes alkaline.

Glycerol broth: Grayish flaky pellicle which breaks up early and settles.

Broth: Slightly turbid; with slight sediment.

Potato: Scanty, grayish growth, raised with a warty surface.

Indole not formed.

Nitrites are produced from nitrates.

Carbohydrates: Glucose, fructose and arabinose are utilized; sucrose, lactose and galactose not utilized (Merrill, Jour. Bact., *20*, 1930, 235). Fructose, mannitol and trehalose are utilized; sorbitol, arabinose and galactose are not utilized (Gordon, Jour. Bact., *34*, 1937, 617).

No H_2S formed.

Optimum temperature 28°C (Küster), 37°C (Bynoe).

Optimum pH 6.6 to 7.3, range 4.0 to 10.0.

Antigenic structure: By agglutination and complement fixation *Mycobacterium ranae* may be distinguished from *Mycobacterium piscium* and *Mycobacterium friedmannii* (Mudd, Proc. Soc. Exp. Biol. and Med., *23*, 1925, 569; Furth, Jour. Immunol., *12*, 1926, 286). See *Mycobacterium piscium*.

Pathogenicity: Experimentally causes tuberculosis in frogs, lizards, turtles; not pathogenic for rabbits, guinea pigs, rats or mice.

Distinctive characters: See *Mycobacterium piscium*.

Source: From the liver of a frog.

Habitat: In a group of 215 cultures belonging to the genus, isolated from soils, Gordon (Jour. Bact., *34*, 1937, 617) found 65 to sufficiently resemble *Mycobacterium ranae* to indicate at least a very close relationship. If they prove to be identical, the species is widely distributed.

9. **Mycobacterium thamnopheos** Aronson. (Jour. Inf. Dis., *44*, 1929, 222.) From *Thamnophis*, a genus of snakes.

Tuberculbacillen bei Schlangen, Sibley, Arch. f. pathol. Anat. u. Physiol., *116*, 1889, 104 (*Mycobacterium tropidonatum* (sic) Bergey et al., Manual, 1st ed., 1923, 376) is probably identical, but the descriptions are too meager to be conclusive. Acid-fast bacilli described by Gibbes and Shurley (Amer. Jour. Med. Sci., *100*, 1890, 145) as the cause of tuberculosis in boas and pythons; by Shattock (Trans. Path. Soc., London, *53*, 1902, 430) and by von Hanseneann (Cent. f. Bakt., I Abt., Orig., *34*, 1903, 212) as causing tuberculosis in a *Python molurus*, are possibly identical, but the descriptions do not permit us to draw any conclusions. According to Aronson, similar organisms isolated from pathological lesions in boa constrictors and *Caluber catenifer* differ antigenically from *Mycobacterium thamnopheos*.

Description taken from Aronson (*loc. cit.*) and Bynoe (Thesis, McGill University, Montreal, 1931).

Slender rods: 0.5 by 4 to 7 microns, frequently slightly curved, beaded and barred forms frequently occur. Non-motile. Acid-fast in cultures of 4 days or older, in younger cultures some organisms are not acid-fast. Not alcohol-fast. Gram-positive.

Gelatin stab: Growth occurs along the line of inoculation. No liquefaction.

Agar colonies: 0.5 to 1 mm in diameter, irregular, raised, moist and glistening.

Glycerol agar: Spreading, raised, dry, pale pink to buff growth.

Glycerol broth: A thin pellicle appears in 5 to 6 days, gradually becomes thicker and falls as a sediment.

Dorset's egg medium: Raised, moist, pinkish growth after 10 days, later becoming salmon-colored.

Loeffler's serum: Small, raised, convex, dry growth.

Litmus milk: Alkaline.

Glycerol potato: Raised, hemispherical, dry and granular growth.

Indole not produced.

Nitrates: Not reduced by 2 strains,

reduced by 1 strain (Aronson); slightly reduced (Gordon); not reduced (Bynoe).

Carbohydrates: Utilizes fructose, mannitol and trehalose; fails to utilize arabinose, sucrose, galactose and sorbitol (Gordon, Jour. Bact., *34*, 1937, 617).

Temperature relations: Fails to survive 60°C for 1 hour, fails to grow at 47°C (Gordon); good growth at 25°C, no growth at 37°C (Aronson); optimum for growth 25°C, range 10° to 35°C (Bynoe).

Range of pH: 6.6 to 7.8 (Aronson); optimum 7.3 to 8.0, range 5.0 to 11.0 (Bynoe).

Pathogenicity: Experimentally produces generalized tuberculosis in snakes, frogs, lizards and fish but not pathogenic for guinea pigs, rabbits or fowls.

Antigenic structure: By agglutination and absorption of agglutinins *Mycobacterium thamnopheos* may be distinguished from *Mycobacterium marinum*, *Mycobacterium friedmannii* and *Mycobacterium ranae*. See *Mycobacterium piscium*.

Variation: According to Bynoe and Wyckoff (Amer. Rev. Tub., *29*, 1934, 389) S and R forms may be distinguished by colony structure and individual cell arrangement.

Distinctive characters: See *Mycobacterium piscium*.

Source: From the lungs and livers of garter snakes (*Thamnophis sirtalis*).

Habitat: Present as a parasite in the garter snake and possibly other cold-blooded vertebrates.

10. **Mycobacterium friedmannii** Holland. (Schildkröten tuberkelbacillus, Friedmann, Cent. f. Bakt., I Abt., Orig., *34*, 1903, 647; *Bacillus friedmanii* (*sic*) Holland, Jour. Bact., *5*, 1920, 218; *Mycobacterium friedmanii* Holland, *ibid.*; *Mycobacterium chelonei* Bergey et al., Manual, 1st ed., 1923, 376.) Named for Dr. Friedmann, who isolated this organism.

Common name: Turtle bacillus.

Description from Friedmann (*loc. cit.*) and Aronson (Jour. Inf. Dis., *44*, 1929, 222).

Slender rods: 0.2 to 0.4 by 0.5 to 5 microns. Beaded forms are common. Acid-alcohol-fast in young cultures but in cultures two weeks old generally there are many non-acid-fast rods. Non-motile. Gram-positive.

Gelatin stab: White surface growth, scanty growth along the line of stab. No liquefaction.

Agar colonies: 1 to 3 mm in diameter, irregularly round, raised, moist, glistening, white.

Glycerol agar slants: Thick, spreading growth, at first moist, later granular, yellowish-white (Friedmann); olive-gray (Bynoe); white (Aronson).

Glycerol broth: Thick wrinkled pellicle after two to three days growth, later some membranous sediment. Grayish-yellow (Friedmann); grayish-white (Bynoe).

Dorset's egg medium: Spreading, raised, slightly moist, pale buff.

Loeffler's serum: Scant growth, raised, dry, crumb-like.

Litmus milk: Slightly alkaline after 10 days growth.

Glycerol potato: Thick, wrinkled, gray after 2 days growth.

Indole not formed.

Carbohydrates: Glucose, fructose and arabinose utilized, sucrose slightly utilized, galactose and lactose not utilized (Merrill, Jour. Bact., *20*, 1930, 235). Arabinose not utilized (Gordon, Jour. Bact., *34*, 1937, 617).

Optimum temperature 25° to 30°C.

Pathogenicity: Experimentally produces tubercles in most species of cold-blooded animals, possibly in guinea pigs but not in other warm-blooded animals.

Variation: According to Gildemeister (Cent. f. Bakt., I Abt., Orig., *86*, 1921, 513) S and R types may be distinguished on glycerol agar. The S grows as smooth, moist, glistening, convex colonies; the R as flat, dry, spreading colonies. Wykoff (Amer. Rev. Tub., *29*, 1934, 289) has shown a difference in the form of cell division and corresponding cell arrangement of the two types.

Distinctive characters: See *Mycobacterium piscium*.

Source: From the lungs of turtles in the Berlin aquarium.

Habitat: A parasite in turtles and possibly sparingly distributed in soils. Gordon (Jour. Bact., *34*, 1937, 617) found 65 out of 215 soil cultures of members of the genus to closely resemble this species.

11. **Mycobacterium spp.** (A miscellaneous group many of which have been incorrectly identified as *Mycobacterium leprae* Lehmann and Neumann.)

Clegg (Phil. Jour. Sci., *4*, 1909, 77 and 403), Duval (Jour. Exp. Med., *12*, 1910, 649), Duval and Wellman (Jour. Inf. Dis., *11*, 1912, 116), Currie, Brinckerhoff and Hollmann (Pub. Health Rep., *25*, 1910, 1173) and others have described as *Mycobacterium leprae* a group of organisms isolated from leprosy lesions. Much evidence, summarized by McKinley (Medicine, *13*, 1934, 377), points to the conclusion that these organisms are not pathogenic and not the causal agent of leprosy. They cannot therefore be included under *Mycobacterium leprae* as defined above.

Thomson (Amer. Rev. Tub., *26*, 1932, 162), Gordon (Jour. Bact., *34*, 1937, 617), and Gordon and Hagan (Jour. Bact., *36*, 1938, 39) recently separated the saprophytic members of the genus *Mycobacterium* into three main groups and several subgroups. Species names as here defined have been added to the key as follows:

Group I. Fail to survive 60°C for 1 hour. Grow at 47°C.
- a. Utilizes arabinose.
  - *Mycobacterium lacticola.*
- b. Unable to utilize arabinose.
  - *Mycobacterium sp.*

Group II. Fail to survive 60°C for 1 hour. Do not grow at 47°C.
- a. Unable to utilize sorbitol.
  - 1. Unable to utilize arabinose.
    - *Mycobacterium ranae.*
    - *Mycobacterium thamnopheos.*
    - *Mycobacterium sp.*
  - 2. Utilize arabinose.
    - *Mycobacterium marinum.*
    - *Mycobacterium sp.*
- b. Utilizes sorbitol.
  - *Mycobacterium spp.*
- c. Unable to utilize most carbohydrates.
  - *Mycobacterium friedmannii.*
  - *Mycobacterium sp.*

Group III. Survive 60°C for 1 hour. Grow at 47°C.
- a. Utilizes arabinose.
  - *Mycobacterium phlei.*
- b. Unable to utilize arabinose.
  - *Mycobacterium sp.*

In this study Gordon and Hagan included many recently isolated soil forms, named saprophytic species, pathogens for cold-blooded animals and 19 cultures, from various collections, which bore the name *Mycobacterium leprae.* Of these so-called *Mycobacterium leprae*, six belong to Group I which corresponds with *Mycobacterium lacticola* and includes many soil forms, two belong to Group IIa which includes *Mycobacterium ranae*, *Mycobacterium thamnopheos* and a number of undefined soil forms, while eleven belong to Group IIb. The latter group includes a number of soil cultures but no other defined species.

In the several groups to which so-called *Mycobacterium leprae* strains belong, some appear to be indistinguishable from soil forms, others are distinguished by habit of growth, utilization of carbohydrates or by pigmentation.

12. **Mycobacterium lacticola** Lehmann and Neumann. (Bakt. Diag., 2 Aufl., *2*,

1899, 409.) From Latin *lac*, *lactis*, milk and *colo*, to dwell; hence, a milk dweller.

From the fact that Lehmann and Neumann (*loc. cit.*, 411) refer to the binomial *Bacillus friburgensis* Korn, it is evident that the species name *friburgensis* (see Appendix) published the same year (1899) has priority over the species name *lacticola*. However, since it has never been used with the broad meaning given *Mycobacterium lacticola* by Lehmann and Neumann in the original description, it is not substituted for the more commonly used *Mycobacterium lacticola* in this edition of the Manual.

Description from Lehmann and Neumann (*loc. cit*) and Jensen (Proc. Linnean Soc. of New So. Wales, *59*, 1934, 19).

Slender rods: 0.5 to 0.7 by 2 to 8 microns in young cultures, in older cultures the rods are shorter and frequently coccoid in shape. Curved and irregular forms occur occasionally. Branched forms, if they occur, are very rare. Staining is generally uniform but slight beading occurs occasionally. Strongly acid-fast except organisms from glucose-containing media which are sometimes only faintly acid-fast. Gram-positive.

Gelatin colonies: Similar to those on agar.

Gelatin stab: Filiform growth in stab. No liquefaction.

Agar colonies: Convex, glistening, with entire margins, at first smooth but after 10 to 14 days growth folded or wrinkled. Opaque, at first white, after 2 or 3 days growth becomes yellow.

Glucose agar: Similar to agar but more rapid growth and less intensely pigmented.

Glycerol agar slants: Spreading, moist, wrinkled, pale cream-colored to yellow.

Nutrient broth: Diffuse growth, later with yellowish pellicle.

Litmus milk: Small white granules of growth at the surface, later a dry yellowish pellicle. After some weeks' growth the milk becomes alkaline and clear. No coagulation.

Dorset's egg medium: As on glycerol agar.

Coagulated serum: As on glycerol agar.

Potato: Spreading, raised, wrinkled growth, pale yellow to orange.

Long's medium lacking glycerol: No growth. Long's medium with 5 per cent glycerol: Acid formed. (Thomson, Amer. Rev. Tub., *26*, 1932, 162.)

Indole not formed.

Nitrates: Reduced, doubtful (Jensen).

Carbohydrates: Glucose, fructose, arabinose and galactose are utilized; lactose is not utilized; sucrose is not utilized by 3 strains, utilized by 1 strain (*Mycobacterium friburgensis*) (Merrill, Jour. Bact., *20*, 1930, 235). Sorbitol, arabinose, galactose, trehalose, mannitol and fructose are utilized; sucrose is not utilized (Gordon, Jour. Bact., *34*, 1937, 617).

Optimum temperature 37°C, maximum temperature for growth 52°C, minimum 15° to 18°C. Fails to survive 60°C for 1 hour, grows at 47°C (Gordon, Jour. Bact., *34*, 1937, 617; Gordon and Hagan Jour. Bact., *36*, 1938, 39).

Optimum pH 6.8 to 7.2. Limits for growth 4.5 to 10.0.

Distinctive characters: Saprophytic acid-fast organism. Grows rapidly on most media, develops a yellow or orange pigmentation after 3 to 4 days growth. Fails to grow on Long's medium lacking glycerol and produces acid when glycerol is present. Fails to survive 60°C for an hour, grows at temperatures as high as 47°C.

Variation: Lehmann and Neumann (Bakt. Diag., 2 Aufl., *2*, 1899, 408) and Haag (Cent. f. Bakt., II Abt., *71*, 1927, 1) describe three forms: a flat smooth form, a moist, slimy, smooth form and a dry, friable perrugose form. The two former correspond with S and the latter with R types described by Bynoe as characteristic of *Mycobacterium stercoris*, *Mycobacterium berolinensis*, *Mycobacterium butyricum* and *Mycobacterium graminis* which in turn correspond with S and R types of other members of the genus. Schwabacher (Spec. Rep. Ser. Med. Res.

Coun., London, No. 182, 1933) finds a difference in the arrangement of the individual cells of the S and R types.

Source: From butter, plant dust, cow manure.

Habitat: Gordon (Jour. Bact., *34*, 1937, 617) found 1 culture isolated from nasal exudate, 1 from bovine lymph gland and 94 isolated from soil, out of a group of 215 soil cultures belonging to the genus, to be either identical with or very closely related to this species. If these strains are valid members of the species, *Mycobacterium lacticola* is widely distributed in soil, dust, dairy products, etc.

13. **Mycobacterium phlei** Lehmann and Neumann. (Timotheebacillus or Grasbacillus I, Moeller, Therapeutischen Monatsheften, *12*, 1898, 607; Moeller, Deut. med. Wchnschr., *24*, 1898, 376; Lehmann and Neumann, Bakt. Diag., 2 Aufl., *2*, 1899, 411; *Mycobacterium moelleri* Chester, Manual Determ. Bact., 1901, 358; *Sclerothrix phlei* Vuillemin, Encyclopédie Mycologique, Paris, *2*, 1931, 160.) From M. L. *Phleum*, a genus of grasses.

Description from Moeller (*loc. cit.*) and Jensen (Proc. Linnean Soc. New So. Wales, *59*, 1934, 32).

Slender rods: 0.2 to 0.5 by 1 to 4 microns, sometimes club-shaped, frequently beaded, rarely branched. Strongly acid-fast and acid-alcohol-fast in cultures older than 2 to 3 days, in younger cultures there are generally many non-acid-fast cells. Non-motile. Gram-positive.

Gelatin colonies: Small, 0.5 to 1 mm in diameter; irregular, raised, moist and glistening, finely granular, orange.

Gelatin stab: Filiform, opaque, orange. No liquefaction.

Agar colonies: Similar to gelatin colonies, yellow to orange.

Agar slant: Spreading, raised, dry with roughened granular surface, yellow to orange.

Broth: Turbid, with yellow pellicle.

Dorset's egg medium: Spreading, raised, dry, orange.

Loeffler's serum: Similar to Dorset's egg medium, creamy to yellow.

Glycerol broth: Thin transparent pellicle, later becoming thickened, rough, wrinkled and yellow to pink, still later a flaky sediment.

Litmus milk: Yellow flocculi on surface, slowly becomes alkaline. No coagulation.

Potato: Thick, dry, yellow, adherent growth.

Long's medium lacking glycerol: Abundant growth. Long's medium with 5 per cent glycerol: No acid formed (Thomson, Amer. Rev. Tub., *26*, 1932, 162).

Nitrites are produced from nitrates.

Indole not formed.

Carbohydrates: Glucose, fructose, arabinose, trehalose, mannitol and galactose are utilized; sucrose and lactose are not utilized (Merrill, Jour. Bact., *20*, 1930, 235; Gordon, Jour. Bact., *34*, 1937, 617).

Temperature relations: Survives 60°C for 1 hour, grows at 47°C (Thomson, Amer. Jour. Tub., *26*, 1932, 162); optimum for growth 37°C, range 20° to 58°C (Bynoe).

Optimum pH 6.8 to 7.3; range 5.5 to 10.0.

Pathogenicity: The injection of large numbers of organisms into guinea pigs results in a local abscess of a few weeks' duration, occasionally small abscesses develop in the regional lymph glands or the visceral organs. According to Mayer (Cent. f. Bakt., I Abt., *26*, 1899, 331) and others, the injection of the organisms along with butter or other fat increases the pathological reaction.

Variation: Haag (Cent. f. Bakt., II Abt., *71*, 1927, 1) and Bynoe (Thesis, McGill University, Montreal, 1931) find two or three colony types: an R form which fits into the description of the species given above and an S type which grows as a perfectly smooth, raised, moist, glistening colony with an entire margin. Cooper (Jour. Inf. Dis., *54*, 1934, 236) distinguished pigmented and non-pigmented types.

Distinctive characters: Saprophyti acid-fast organism, grows rapidly on most media. Shows yellow pigmentation as soon as growth is visible. Grows well on Long's medium lacking glycerol and fails to produce acid when glycerol is present. Survives 60°C for 1 hour and grows at 47°C.

Source: Originally isolated from hay and grass. Frequently found in soil, dust and other sources. Out of 215 cultures of the genus recovered from soils by Gordon (Jour. Bact., *34*, 1937, 617) *Mycobacterium phlei* was isolated on 22 occasions. The same author reports 3 cultures of a closely related if not identical organism recovered from bovine lymph glands, 1 recovered from bovine skin and 1 recovered from a hen's spleen.

Habitat: Widely distributed in soils, dust, hay, etc.

Appendix I: The following saprophytic species have been placed in this genus. Their relationships are not clear. Some are related to or possibly identical with *Mycobacterium lacticola*.

Mycobacterium album Söhngen. (Cent. f. Bakt., II Abt., *37*, 1913, 599.) From garden earth.

Mycobacterium bekkerii Bekker. (Antonie van Leeuwenhoek, *9*, 1943, 81; abst. in Cent. f. Bakt., I Abt., Orig., *149*, 1944, 500.) From urine.

Mycobacterium berolinense Bergey et al. (Tuberkelähnlichen Bacillen, Rabinowitsch, Ztschr. f. Hyg., *26*, 1897, 90; *Mycobacterium lacticola β perrugosum* Lehmann and Neumann, Bakt. Diag., 2 Aufl., *2*, 1899, 410; *Mycobacterium lacticola perrugosum* Haag, Cent. f. Bakt., II Abt., *71*, 1927, 3; Bergey et al., Manual, 1st ed., 1923, 377.) From butter.

Mycobacterium butyri Chester. (Man. Determ. Bact., 1901, 357.) This name includes both the Tuberkelähnlichen Bacillen of Rabinowitsch and the Butter Bacillus of Petri. From butter.

Mycobacterium butyricum Bergey et al. (Butter Bacillus, Petri, Arb. kaiserl. Gesundheitsamte, *14*, 1898, 1; Bergey et al., Manual, 1st ed., 1923, 377.) From butter.

Mycobacterium cholesterolicum Tak. (Antonie van Leeuwenhoek, *8*, 1942, 39.) From garden soil.

Mycobacterium friburgensis (Korn) Chester. (*Bacillus friburgensis* Korn, Cent. f. Bakt., I Abt., *25*, 1899, 532; *Mycobacterium lacticola γ friburgensis* Lehmann and Neumann, Bakt. Diag., 2 Aufl., *2*, 1899, 411; Chester, Man. Determ. Bact., 1901, 359.) From butter.

Mycobacterium graminis Chester. (Grasbacillus II, Moeller, Cent f. Bakt., I Abt., *25*, 1899, 369; *Mycobacterium lacticola α planum* Lehmann and Neumann, Bakt. Diag., 2 Aufl., *2*, 1899, 408; Chester, Man. Determ. Bact., 1901, 358; *Mycobacterium lacticola planum* Haag, Cent. f. Bakt., II Abt., *71*, 1927, 3.) From hay dust.

Mycobacterium hyalinum Söhngen. (Cent. f. Bakt., II Abt., *37*, 1913, 599.) From garden earth.

Mycobacterium luteum Söhngen (*loc. cit.*). From garden earth.

Mycobacterium muris Simmons. (Jour. Inf. Dis., *41*, 1927, 13.) From the feces of gray mice.

Mycobacterium phlei perrugosum Haag. (Cent. f. Bakt., II Abt., *71*, 1927, 6.) From soils and manure.

Mycobacterium phlei planum Haag (*loc. cit.*). From soils.

Mycobacterium ranicola I and *II* Haag (*loc. cit.*). From frogs.

Mycobacterium rubrum Söhngen (*loc. cit.*). From garden earth.

Mycobacterium smegmatis (Trevisan) Chester. (Smegma bacillus, Alvarez and Tavel, Arch. Phys. norm. et path., *6*, 1885, 303; *Bacillus smegmatis* Trevisan, I generi e le specie delle Batteriacee, 1889, 14; *Bacterium smegmatis* Migula, Syst. d. Bakt., *2*, 1900, 497; Chester, Man. Determ. Bact., 1901, 357.) From smegma. Weber (Arb. kaiserl. Gesundheitsamte, *19*, 1902, 251) finds *Mycobacterium smegmatis* acid- but not alcohol-fast in contrast to the mammalian

tubercle bacilli which are both acid- and alcohol-fast. Later observers (Bynoe, Thesis, McGill University, Montreal, 1931) have not found this a valid distinction.

Mycobacterium smegmatis var. *muris* Galli-Valerio. (Cent. f. Bakt., I Abt., Orig., *75*, 1915, 49.) From the preputial glands of the black rat (*Mus rattus*).

Mycobacterium stercoris Bergey et al. (Mist Bacillus, Moeller, Berlin. thierärztl. Wochnschr., 1898, 100; *Mycobacterium stercusis* (sic) Bergey et al., Manual, 1st ed., 1923, 378; Bergey et al., Manual, 4th ed., 1934, 542.) From manure.

Mycobacterium testudinis Friedmann and Piorkowski. (See Haag, Cent. f. Bakt., II Abt., *71*, 1927, 5; apparently the same as *Mycobacterium testudo*, *loc. cit.*, 10.) This is probably *Mycobacterium friedmannii*. From turtles.

Appendix II: Krassilnikov (Mikrobiol., *7*, 1938, 335; and Ray Fungi and Related Organisms, Izd. Acad. Nauk. Moskow, 1938, 121–130) describes a genus *Mycococcus* distinct from Hansgirg's (Österr. Bot. Ztschr., *38*, 1888, 266) family *Mycococcaceae* (which is related to the fungi) and distinct from *Mycococcus* Bokor (Arch. f. Mikrobiol., *1*, 1930, 1).

Mycococcus Krassilnikov includes species that produce coccus-like cells, genetically related to the species included in *Mycobacterium;* reproduction is by fission or budding in different directions, often forming short, irregular chains with side branches; in old cultures, the vegetative cells change into resting cells, the latter germinating in a manner similar to the spores of actinomycetes. Seven species are listed, with incomplete descriptions. *Mycococcus ruber*, *M. capsulatus*, *M. luteus*, *M. citreus* and *M. albus* are described in Krassilnikov's original paper. One of these (*Mycococcus luteus*) is dropped in his later monograph while descriptions of two new species are added (*Mycococcus tetragenus* and *M. mucosus*).

FAMILY II. ACTINOMYCETACEAE BUCHANAN.*

(Jour. Bact., *3*, 1918, 403.)

Mycelium is non-septate during the early stages of growth but later may become septate and break up into short segments, rod-shaped or spherical in shape, or the mycelium may remain non-septate and produce spores on aerial hyphae. The organisms in culture media are either colorless or produce various pigments. Some species are partially acid-fast. This family is distinguished from the previous one by the formation of a true mycelium. As compared with the next family, it is characterized by the manner of spore formation.

Key to the genera of family **Actinomycetaceae.**

I. Obligate aerobic. The colonies are bacteria-like in nature, smooth, rough or folded, of a soft to a dough-like consistency, sometimes compact and leathery in young stages. Most forms do not produce any aerial mycelium; a few produce a limited mycelium, the branches of which also break up into oidiospores or segmentation spores. Some species are partially acid-fast.

Genus I. *Nocardia*, p. 892.

II. Anaerobic or microaerophilic, parasitic; non-acid-fast, non-proteolytic and non-diastatic.

Genus II. *Actinomyces*, p. 925.

Genus I. Nocardia *Trevisan.*

(Trevisan, I generi e le specie delle Batteriacee, 1889, 9; *Actinomyces* Gasperini, Cent. f. Bakt., *15*, 1894, 684 and Atti dell' XI congresso med. internaz. Roma, *6*, 1895, 82; not *Actinomyces* Harz, Jahresber. d. Münch. Thierarzneischule for 1877–1878, 1879, 125; *Actinobacterium* Haas, Cent. f. Bakt., I Abt., Orig., *40*, 1906, 180; Sampietro, Ann. d'Igiene, Roma, *18*, 1908, 331; *Actinococcus* Beijerinck, Folio Microbiol., Delft, *3*, 1914, 196; not *Actinococcus* Kützing, Species Algarum, 1849; *Brevistreptothrix* Lignières, Ann. Parasit. hum. et comp., *2*, 1924, 1; *Asteroides* Puntoni and Leonardi, Boll. e Atti d. R. Accad. Med., *61*, 1935, 90; *Proactinomyces* Jensen, Proc. Linn. Soc. New So. Wales, *56*, 1931, 345.) Named for Prof. E. Nocard who first described the type species.

Slender filaments or rods, frequently swollen and occasionally branched, forming a mycelium which after reaching a certain size assumes the appearance of bacterium-like growths. Shorter rods and coccoid forms are found in older cultures. Conidia not formed. Stain readily, occasionally showing a slight degree of acid-fastness. Non-motile. No endospores. Aerobic. Gram-positive. The colonies are similar in gross appearance to those of the genus *Mycobacterium*. Paraffin, phenol and m-cresol are frequently utilized as a source of energy.

In their early stages of growth on culture media (liquid or solid), the structure of nocardias is similar to that of actinomyces in that they form a typical mycelium hyphae branch abundantly, the branching being true. The diameters of the hyphae vary between 0.5 and 1 micron, usually 0.7 to 0.8 micron, according to the species. The mycelium is not septate. However, the further development of nocardias differs sharply from that of actinomyces: the filaments soon form transverse walls and the whole mycelium breaks up into regularly cylindrical short cells, then into coccoid

* Completely revised by Prof. S. A. Waksman, New Jersey Experiment Station, New Brunswick, New Jersey and Prof. A. T. Henrici, University of Minnesota, Minneapolis, Minnesota, May, 1943.

cells. On fresh culture media, the coccoid cells germinate into mycelia. The whole cycle in the development of nocardias continues for 2 to 7 days. Most frequently the coccoid cells are formed on the third to fifth day, but in certain species (e.g., *Nocardia rubra*) they can be found on the second day.

Numerous chlamydospores may be found in older cultures of nocardias. They are formed in the same way as the chlamydospores in true fungi: the plasma inside the filaments of the mycelium condenses into elongated portions. In older cultures of nocardias many coccoid cells are changed into resistant cells. The latter are larger than the vegetative coccoid cells; the plasma of these cells is thicker than the plasma of vegetative cells; on fresh media they germinate like the spores of actinomyces; they form 2 to 3 germ tubes. Besides the cells mentioned, numerous involution forms can often be found in older cultures of nocardias; the cells are thin, regularly cylindrical or coccoid, are often transformed into a series of spherical or elliptical ampules and a club-like form (2 to 3 microns and more).

The multiplication of nocardias proceeds by fission and budding; occasionally they form special spores. Budding occurs often. The buds are formed on the lateral surface of the cells; when they have reached a certain size, they fall off and develop into rod-shaped cells or filaments. The spores are formed by the breaking up of the cell plasm into separate portions usually forming 3 to 5 spores; every portion becomes rounded, covered with a membrane and is transformed into a spore; the membrane of the mother cell dissolves and disappears. The spores germinate in the same way as those of actinomyces. They form germ tubes which develop into a mycelium.

The colonies of nocardias have a paste-like or mealy consistency and can easily be taken up with a platinum loop; they spread on glass and occasionally render the broth turbid. The surface colonies are smooth, folded or wrinkled. Typical nocardias never form an aerial mycelium, but there are cultures whose colonies are covered with a thin coating of short aerial hyphae which break up into cylindrical oidiospores.

Many species of nocardias form pigments; their colonies are of a blue, violet, red, yellow or green color; more often the cultures are colorless. The color of the culture serves as a stable character.

Krassilnikov (Ray fungi and related organisms, Izd. Acad. Nauk, U.S.S.R., Moscow, 1938) divides the genus into two groups: 1. Well developed aerial mycelium; substrate mycelium seldom produces cross-walls; the threads break up into long, thread-like rods; branches of the aerial mýcelium produce segmentation spores and oidiospores; the latter are cylindrical with sharp ends; no spirals or fruiting branches. This group is the same as group B of Jensen (*loc. cit.*). 2. Typical forms; mycelium develops only at early stages of growth, then breaks up into rod-shaped and coccoid bodies; smooth and rough colonies, dough-like consistency; never form an aerial mycelium; similar to bacterial colonies; aerial mycelium may form around colonies. This genus can also be divided, on the basis of acid-fastness, into two groups: Group 1. Partially acid-fast organisms, which are non-proteolytic, non-diastatic and utilize paraffin; usually yellow, pink, or orange-red in color. Group 2. Non-acid-fast organisms, which are diastatic, largely proteolytic and do not utilize paraffin; yellow, orange to black in color.

The type species is *Nocardia farcinica* Trevisan.

Key to the species of genus **Nocardia.**

I. Partially acid-fast* organisms with strongly refractive cells; non-proteolytic and generally non-diastatic; constantly capable of utilizing paraffin.

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* Acid-fastness is not marked in cultures, is apparent in infected tissues, pronounced in sputum or other exudates.

A. Initial mycelium well developed, richly branching, dividing into rods and generally into cocci.
    1. Vegetative mycelium soft, without macroscopically visible aerial mycelium.
        a. Vegetative mycelium yellow, orange or red.
            b. Pathogenic.
                c. Vegetative mycelium white, buff, or pale yellow.
                    1. *Nocardia farcinica.*
                cc. Vegetative mycelium yellow to red.
                    2. *Nocardia asteroides.*
            bb. Not pathogenic.
                    3. *Nocardia polychromogenes.*
        aa. Vegetative mycelium white to pink.
            b. Gelatin not liquefied.
                c. Growth on nutrient agar opaque, cream-colored; coccoid forms in broth.
                    4. *Nocardia opaca.*
                cc. Growth on nutrient agar watery, no coccoid forms in broth.
                    5. *Nocardia erythropolis.*
                ccc. Growth on nutrient agar pink.
                    d. White aerial mycelium on milk.
                        6. *Nocardia leishmanii.*
                    dd. Pink pellicle on milk.
                        7. *Nocardia caprae.*
                    ddd. Yellow pellicle on milk.
                        8. *Nocardia pretoriana.*
            bb. Gelatin liquefied.
                    9. *Nocardia pulmonalis.*
    2. Vegetative mycelium hard, yellow, with white aerial mycelium; hyphae divide into chains of acid-fast cocci.
                    10. *Nocardia paraffinae.*

B. Initial mycelium very short, rapidly dividing into rods and cocci.
    1. Slowly growing organisms; cells 0.5 to 0.7 micron in diameter.
                    11. *Nocardia minima.*
    2. Rapidly growing organisms; cells 1.0 to 1.2 microns in diameter.
        a. Growth pink.
            b. Cystites (swollen cells) not formed.
                c. No indigotin from indole.
                    12. *Nocardia corallina.*
                cc. Indigotin from indole.
                    13. *Nocardia globerula.*
            bb. Cystites formed.
                    14. *Nocardia salmonicolor.*
        aa. Growth coral red.
                    15. *Nocardia rubropertincta.*
        aaa. Growth dark red.
                    16. *Nocardia rubra.*
        aaaa. Growth white.
            b. No aerial mycelium.
                    17. *Nocardia coeliaca.*
            bb. Aerial mycelium.
                    18. *Nocardia transvalensis.*

II. Non-acid-fast organisms with weakly refractive cells; no distinct formation of cocci. Constantly diastatic.

A. Not proteolytic.

1. Growth on agar pale cream.
   19. *Nocardia mesenterica.*
2. Growth on agar yellow.
   20. *Nocardia flava.*
3. Growth on agar green.
   21. *Nocardia viridis.*
4. Growth on agar yellow-green.
   22. *Nocardia citrea.*
5. Growth on agar pink to crimson.
   23. *Nocardia madurae.*
6. Growth consistency soft, sparse aerial mycelium.
   24. *Nocardia lutea.*
7. Growth consistency medium, good aerial mycelium.
   25. *Nocardia blackwellii.*
8. Good action on milk. Growth consistency firm, liberal, aerial mycelium.
   26. *Nocardia cuniculi.*
9. Deep brown pigment on protein media.
   27. *Nocardia rangoonensis.*
10. Light brown pigment on protein media.
   28. *Nocardia caviae.*

B. Proteolytic.

1. Growth on nutrient agar with rapid formation of unbranched diphtheroid-like rods; no typical cystites; broth turbid.
   29. *Nocardia actinomorpha.*
2. Growth on nutrient agar with extensive mycelia; simple unbranched rods not formed; cystites present. Broth clear.
   30. *Nocardia flavescens.*
3. Colonies orange-yellow to orange-red, which may change to black.
   31. *Nocardia maculata.*
4. Light brown pigment on protein media.
   32. *Nocardia rhodnii.*
5. Green to greenish-brown pigment on protein media.
   33. *Nocardia gardneri.*

1. **Nocardia farcinica** Trevisan. (Bacille du farcin, Nocard, Ann. Inst. Past., *2*, 1888, 293; Trevisan, I generi e le specie delle Batteriacee, Milan, 1889, 9; *Streptotrix farcinica* Rossi Doria, Ann. d. Ist. d'Igi. Sper. Univ. di Roma, *1*, 1891, 424; *Actinomyces farcinicus* Gasperini, Ann. Ist. d'Igiene, Roma, *2*, 1892, 222; *Oospora farcinica* Sauvageau and Radais, Ann. Inst. Past., *6*, 1892, 248; *Actinomyces bovis farcinicus* Gasperini, Cent. f. Bakt., *15*, 1894, 684; *Bacillus farcinicus* Gasperini, *ibid.*; *Cladothrix farcinica* Macé, Traité de Bactériologie, 3rd ed., 1894, 1047; *Streptothrix farcini bovis* Kitt, Bakterienkunde und pathologische Mikroskopie, Vienna, 3 Aufl., 1899, 511; *Bacterium nocardi* Migula, Syst. d. Bakt., *2*, 1900, 345; *Streptothrix nocardii* Foulerton, Jour. Compt. Path. and Therap., *14*, 1901, 51; *Discomyces farcinicus* Gedoelst, Les champignons parasites de l'homme et des animaux domestiques, Brussels, 1902, 167; *Ac-*

tinomyces nocardii Buchanan, Veterinary Bacteriology, Philadelphia, 1911, 378; *Nocardia albida* Chalmers and Christopherson, Ann. Trop. Med. and Parasit., *10*, 1916, 271, according to Dodge, Medical Mycology, St. Louis, 1935, 746.) From M. L. *farcinicus*, of farcy.

Filaments 0.25 micron in thickness, branched. Markedly acid-fast.

Gelatin colonies: Small, circular, transparent, glistening.

Gelatin stab: No liquefaction.

Agar colonies: Yellowish-white, irregular, refractive, filamentous.

Agar slant: Grayish to yellowish-white growth, surface roughened.

Broth: Clear, with granular sediment, often with gray pellicle.

Litmus milk: Unchanged.

Potato: Abundant, dull, crumpled, whitish-yellow growth.

Nitrites not produced from nitrates.

No soluble pigment formed.

Proteolytic action absent.

Starch not hydrolyzed.

Aerobic, facultative.

Optimum temperature 37°C.

Source: From cases of bovine farcy.

Habitat: Associated with a disease in cattle, resembling chronic tuberculosis. Transmissible to guinea pigs, cattle and sheep, but not to rabbits, dogs, horses or monkeys.

2. **Nocardia asteroides** (Eppinger) Blanchard. (*Cladothrix asteroides* Eppinger, Beitr. z. path. Anat., *9*, 1891, 287; *Streptotrix* (sic) *eppingerii* Rossi Doria, Ann. Inst. d'Ig. sper. d. Univ. Roma, *1*, 1891, 423; *Streptotrix* (sic) *asteroides* Gasperini, Ann. Inst. d'Ig. sper. d. Univ. Roma, *2*, 1892, 183; *Oospora asteroides* Sauvageau and Radais, Ann. Inst. Past., *6*, 1892, 252; *Actinomyces asteroides* Gasperini, Cent. f. Bakt., *15*, 1894, 684; Blanchard, in Bouchard, Traité Path. Gén., *2*, 1895, 811; *Discomyces asteroides* Gedoelst, Champ. Paras. Homme et Anim., 1902, 173; *Actinomyces eppingeri* Namyslowski, Cent. f. Bakt., I Abt., Orig., *62*, 1912, 566; *Asteroides asteroides* Puntoni and Leonardi, Boll. e Atti d. R. Accad. Med. di Roma, *61*, 1935, 92; *Mycobacterium asteroides*, quoted from Puntoni and Leonardi, *idem; Proactinomyces asteroides* Baldacci, Soc. Internat. di Microb., Boll. d. Sez. Ital., *9*, 1937, 141.) From Greek *aster*, star and *eidos*, shape.

Probable synonyms: *Streptotrix aurantiaca* Rossi Doria, *loc. cit.*, 417 (*Actinomyces aurantiacus* Gasperini, *loc. cit.*, 1892, 222; *Oospora aurantiaca* Lehmann and Neumann, Bakt. Diag., 1 Aufl., *2*, 1896, 388; *Cladothrix aurantiaca* Macé, Traité Pratique de Bact., 4th ed., 1901, 1096; *Nocardia aurantiaca* Chalmers and Christopherson, Ann. Trop. Med. and Parasit., *10*, 1916, 268) and *Streptothrix freeri* Musgrave and Clegg, Philippine Jour. Sci., Med. Sciences, *2*, 1907, 477 (*Discomyces freeri* Brumpt, Précis de Parasitol., Paris, 1st ed., 1910, 858; *Nocardia freeri* Pinoy, Bull. Inst. Past., *11*, 1913, 936; *Oospora freeri* Sartory, Champ. Paras. Homme et Anim., 1923, 785; *Actinomyces freeri* Bergey et al., Manual, 1st ed., 1923, 346). According to Chalmers and Christopherson (*loc. cit.*) another synonym of this organism is *Streptothrix hominis* Sabrazès and Rivière, Le Semaine Médecine, 1895, no. 44.

Straight, fine mycelium, 0.2 micron in thickness, which breaks up into small, coccoid conidia. Acid-fast.

Gelatin stab: Yellowish surface growth. No growth in stab. No liquefaction.

Synthetic agar: Thin, spreading, orange growth. No aerial mycelium.

Starch agar: Restricted, scant, orange growth.

Plain agar: Much folded, light yellow growth, becoming deep yellow to yellowish-red

Glucose broth: Thin, yellowish pellicle.

Litmus milk: Orange-colored ring. No coagulation. No peptonization.

Potato: Growth much wrinkled, whitish. becoming yellow to almost brick-red.

Nitrites produced from nitrates.

No soluble pigment formed.

Proteolytic action doubtful.

Starch not hydrolyzed.

Transmissible to rabbits and guinea pigs but not to mice.

Aerobic.

Optimum temperature 37°C.

Source: From a cerebral abscess in man.

Habitat: Also found in conditions resembling pulmonary tuberculosis.

A number of strains of acid-fast actinomycetes isolated from human lesions have deviated in certain particulars from the description of *Nocardia asteroides*, but not sufficiently to warrant separation as species. The following varieties are described by Baldacci (Mycopathologia, *1*, 1938, 68):

Nocardia asteroides var. *crateriformis* (Baldacci) *comb. nov.* (*Proactinomyces asteroides* var. *crateriformis* Baldacci, *loc. cit.*) Less tendency to fragmentation of mycelium. Complete lack of aerial mycelium. Growing as discrete colonies, disk- or crater-shaped.

Nocardia asteroides var. *decolor* (Baldacci) *comb. nov.* (*Proactinomyces asteroides* var. *decolor* Baldacci, *loc. cit.*) Greater tendency to produce white aerial mycelium; vegetative mycelium colorless.

Nocardia asteroides var. *gypsoides* (Baldacci) *comb. nov.* (*Actinomyces gypsoides* Henrici and Gardner, Jour. Inf. Dis., *28*, 1921, 248; *Discomyces gypsoides* Brumpt, Précis de Parasitol., Paris, 3rd ed., 1922, 980; *Oospora gypsoides* Sartory, Champ. Paras. Homme et Anim., 1923, 802; *Proactinomyces asteroides* var. *gypsoides* Baldacci, *loc. cit.*) White aerial mycelium; darkening of peptone media.

3. Nocardia polychromogenes (Vallée) *comb. nov.* (*Streptothrix polychromogenes* Vallée, Ann. Inst. Past., *17*, 1903, 288; *Streptothrix pluricromogena* Caminiti, Cent. f. Bakt., I Abt., Orig., *44*, 1907, 198; *Actinomyces polychromogenes* Lieske, Morphol. u. Biol. d. Strahlenpilze, Leipzig, 1921, 32; *Proactinomyces polychromogenes* Jensen, Proc. Linnean Soc. New So. Wales, *56*, 1931, 79 and 363; *Oospora polychromogenes* Sartory, quoted from Nannizzi, in Pollacci, Tratt. Micopat. Umana, *4*, 1934, 51; *Actinomyces plurichromogenus* Dodge, Medical Mycology, St. Louis, 1935, 737.) From Greek, producing many colors.

Description from Jensen (*loc. cit.*).

Long wavy filaments: 0.4 to 0.5 by 70 to 100 microns, extensively branched but without septa. Older cultures consist entirely of rods 4 to 10 microns, frequently in V, Y, or smaller forms. Still older cultures consist of shorter rods and coccoid forms. Gram-positive, frequently showing bands and granules.

Gelatin stab: Thin yellowish growth along the stab with thin radiating filaments. Surface growth flat, wrinkled, red. No liquefaction.

Nutrient agar: Scant, orange-red growth.

Glucose agar: After 3 to 4 days raised, flat, glistening, rose-colored growth. After 1 to 3 weeks becoming folded and coral-red.

Glucose broth: After 3 to 4 days turbid; after 2 to 3 weeks an orange flaky sediment. No surface growth.

Milk: Growth starts as small orange-colored surface granules. After 1 to 2 weeks a thick, soft, orange-colored sediment forms.

Optimum temperature 22° to 25°C.

Distinctive characters: Differs from *Nocardia corallina* in the formation of very long filaments and in filiform growth in gelatin stabs.

Source: From the blood of a horse; from soil in France and Australia.

Habitat: Soil.

4. Nocardia opaca (den Dooren de Jong) *comb. nov.* (*Mycobacterium opacum* den Dooren de Jong, Cent. f. Bakt., II Abt., *71*, 1927, 216; *Mycobacterium crystallophagum* Gray and Thornton, Cent.

f. Bakt., II Abt., 73, 1928, 86; *Actinomyces crystallophagus* Bergey et al., Manual, 3rd ed., 1930, 473; *Proactinomyces opacus* Jensen, Proc. Linnean Soc. New So. Wales, 57, 1932, 369; *Proactinomyces crystallophagus* Reed, in Manual, 5th ed., 1939, 834.) From Latin *opacus*, shady, darkened.

Description from Gray and Thornton (*loc. cit.*), Bynoe (Thesis, McGill University, Montreal, 1931), and Jensen (*loc. cit.*).

Long, curved, irregular and branching filaments or rods: 0.8 to 1.0 by 2 to 16 microns, or occasionally longer. Few chains or clumps are formed. In older cultures shorter rods or cocci are generally formed. Readily stained. Not acid-fast. Gram-positive.

Gelatin colonies: Round, convex, whitish, smooth, shining, edges slightly arborescent. Deep colonies: Burrs, with slightly irregular processes.

Gelatin stab: Convex, whitish, smooth, resinous, filiform, erose.

Broth: Turbid with broken white scum, or clear with granular suspension.

Dorset's egg medium: Spreading, smooth, moist, salmon-colored growth.

Loeffler's medium: Scanty growth, smooth, moist, light buff-colored.

Glycerol potato: Dry, rough, crumpled, pink to buff-colored growth.

Litmus milk: Grayish pellicle; slightly alkaline.

Nitrites are produced from nitrates.

No acid from sucrose, lactose, maltose or glucose.

Phenol and naphthalene are utilized as sources of energy.

Optimum pH 6.8 to 7.3.

Optimum temperature 30°C.

Distinctive characters: Differs from *Nocardia corallina* and *Nocardia polychromogenes* in that the cells are much longer than those of the former and much shorter than those of the latter. Grows in smooth convex surface colonies and burr-like deep colonies.

Source: Twenty-four strains isolated from soils in Great Britain.

Habitat: Probably sparingly distributed in soils.

5. **Nocardia erythropolis** (Gray and Thornton) *comb. nov.* (*Mycobacterium erythropolis* Gray and Thornton, Cent. f. Bakt., II Abt., 73, 1928, 87; *Actinomyces erythropolis* Bergey et al., Manual, 3rd ed., 1930, 472; *Proactinomyces erythropolis* Jensen, Proc. Linnean Soc. of New So. Wales, 57, 1932, 371.) From Greek *erythrus*, red and *polis*, city.

Description from Gray and Thornton (*loc. cit.*) and from Bynoe (Thesis, McGill University, Montreal, 1931).

Long uneven-sided rods and filaments, curved and branching up to 11 microns long by 0.8 micron. Coccoid forms not formed. Stains readily. Not acid-fast. Gram-positive.

Gelatin colonies: After 12 days, round, flat, white, shining; edge entire. Deep colonies: Round, smooth.

Gelatin stab: After 8 to 14 days, convex, white, smooth, shining, radiate from center, borders cleft. Line of puncture filiform, erose.

Agar colonies: Round, 2 to 3 mm in diameter, convex, watery-white; edge entire. Deep colonies: Lens-shaped.

Agar slant: Filiform, flat, watery growth; edge undulate.

Broth: Growth slight, turbid.

Dorset's egg medium: After 2 weeks, raised, moist, finely granular, irregular margin, flesh-colored.

Loeffler's medium: After 7 days growth as on Dorset's egg medium, but pink.

Glycerol potato: After 7 days, flat, dry, rough, orange-colored.

Litmus milk: Pale pink pellicle.

Nitrites not produced from nitrates.

No acid from glucose, lactose, sucrose or glycerol.

Phenol is utilized.

Optimum pH 6.8 to 8.0.

Optimum temperature 25°C.

Distinctive characters: Differs from *Nocardia coeliaca* and *Nocardia actinomorpha* in the filiform growth and absence of liquefaction of gelatin. Long rods and filaments.

Source: Six strains isolated from soils in Great Britain.

Habitat: Presumably soil.

6. **Nocardia leishmanii** Chalmers and Christopherson. (A new acid-fast streptothrix, Birt and Leishman, Jour. Hyg., *2*, 1902, 120; Chalmers and Christopherson, Ann. Trop. Med. and Parasit., *10*, 1916, 255; *Discomyces leishmani* Brumpt, Précis de Parasitol., Paris, 3rd ed., 1922, 984; *Actinomyces leishmani* Sartory and Bailly, Mycoses pulmonaires, 1923, 253.) Named for Leishman, one of the original isolators.

Description from Erikson (*loc. cit.*, p. 27).

Initial cells frequently swollen, large and irregular, aggregated in short chains and then branching out into regular narrow filaments; at margin of colony on synthetic glycerol agar may be seen comparatively long thick segments with accompanying fringe of normal hyphae; later entire colonies asteroid in appearance, very fine and close angular branching, with aerial hyphae situated singly; aerial mycelium generally abundant with irregularly cylindrical conidia. Slightly acid-fast. The latter property must have been attenuated during artificial cultivation, for the organism is reported as markedly acid-fast by the original isolators.

Gelatin: Small pink colonies in depths of stab. No liquefaction.

Glucose agar: Rounded elevated colonies with paler frosting of aerial mycelium; growth becoming piled up, aerial mycelium sparse.

Glycerol agar: Small round pink colonies, tending to be umbilicated and piled up, stiff white aerial spikes.

Coon's agar: Small round colorless colonies, stiff white aerial spikes; later a pink tinge.

Potato agar: Minute colorless round colonies, small raised patches of white aerial mycelium.

Dorset's egg medium: Colorless confluent growth studded with little wart-like projections bearing stiff aerial spikes; growth becomes pinkish with a white aerial mycelium; later, growth drab gray, medium discolored.

Serum agar: Minute round colorless colonies with pinkish tinge in confluent raised patch.

Inspissated serum: Small round pale pink colonies, umbilicated and raised up.

Broth: Liberal growth, white flocculent colonies; later pink surface colonies.

Synthetic sucrose solution: Colorless flocculent sediment, thin colorless pellicle.

Milk: Surface growth, white aerial mycelium, solid coagulum; later partly peptonized with pink aerial mycelium.

Litmus milk: Pink surface growth, aerial mycelium, milky opaque after 40 days.

Carrot plug: Small irregularly round raised colonies, colorless, covered with stiff aerial spikes; later buff-colored, convoluted and ribbed growth with small patches of white aerial mycelium; aerial mycelium pink in two months.

Source: From fatal case of lung disease and pericarditis in man.

Habitat: Human infections so far as known.

7. **Nocardia caprae** (Silberschmidt) *comb. nov.* (*Streptothrix caprae* Silberschmidt, Ann. Inst. Past., *13*, 1899, 841; *Cladothrix caprae* Macé, Traité Pratique de Bact., 4th ed., 1901, 1094; *Discomyces caprae* Gedoelst, Champ. Paras. Homme et Anim., 1902, 174; *Oospora caprae* Sartory, Champ. Paras. Homme et Anim., 1923, 813; *Actinomyces caprae* Ford, Textb. of Bact., 1927, 205.) From Latin *capra*, goat.

Description from Erikson (Med. Res. Council Spec. Rept. Ser. 203, 1935, 26).

Initial cells only slightly enlarged; early development of aerial hyphae, while substratum threads are still short; frequent slipping of branches; aerial mycelium abundant on all media with tendency to form coherent spikes; mycelium not very polymorphous, but occasional thicker segments appear. Slightly acid-fast.

Gelatin: Extensive dull growth with small raised patches of pink aerial mycelium; later ribbon-like, depressed. No liquefaction.

Glucose agar: Irregular bright pink growth tending to be heaped up; later abundant masses frosted over with thin white aerial mycelium.

Glycerol agar: Abundant growth, small round pink colonies, partly covered with white aerial mycelium.

Potato agar: Extensive thin growth, pink in raised patches, covered by white aerial mycelium; later aerial mycelium also becomes pink.

Starch agar: Minute colorless colonies covered by white aerial mycelium.

Blood agar: Minute round colorless colonies aggregated in broad pink zones, paler aerial mycelium. No hemolysis.

Dorset's egg medium: Few colorless colonies, some pink, white aerial mycelium; later, growth becoming dull pink, irregular, with scant white aerial mycelium.

Ca-agar: Minute colorless colonies, white aerial mycelium; later a pinkish tinge.

Serum agar: Small round pink colonies frosted over with thin white aerial mycelium.

Inspissated serum: No growth.

Broth: Superficial pellicle composed of pink colonies with white aerial mycelium; moderate flocculent sediment.

Glucose broth: Small sediment of fine flocculi; later pellicle composed of small pink colonies; superficial skin entire and salmon-colored in 16 days.

Synthetic glycerol solution: Round pink disc-like colonies on surface and tenuous white wispy growth in suspension and sediment; after 20 days, surface colonies bearing white aerial mycelium extending 2 cm up tube.

Synthetic sucrose solution: Minute white colonies in suspension and sediment in 3 days; thin dust-like pellicle in 10 days; some surface colonies with white aerial mycelium in 17 days.

Milk: Red surface skin; solid coagulum.

Litmus milk: Red surface growth, no change in liquid; after 4 weeks, liquid decolorized, opaque.

Potato plug: Abundant growth, small colonies, mostly confluent, entirely covered with pale pink aerial mycelium; growth becomes membranous, considerably buckled; later superficial colonies with pink aerial mycelium on liquid at base of tube, bottom growth of round white colonies.

Starch not hydrolyzed.

Source: From lesions in goats.

8. **Nocardia pretoriana** Pijper and Pullinger. (Pijper and Pullinger, Jour. Trop. Med. Hyg., *30*, 1927, 153; *Actinomyces pretorianus* Nannizzi, in Pollacci, Tratt. Micopat. Umana, *4*, 1934, 38.) Named for Pretoria in South Africa.

Description from Erikson. (Med. Res. Council Spec. Rept. Ser. 203, 1935, 30).

Minute flat colonies are formed consisting of angularly branched filaments, and bearing a few short straight aerial hyphae; later the growth becomes spreading and extensive, the slipping of the branches is well marked and the aerial hyphae are divided into cylindrical conidia. Slightly acid-fast.

Gelatin: A few colorless flakes. No liquefaction.

Glucose agar: Pale buff umbilicated and piled up colonies.

Glycerol agar: Piled up pink mass, very scant white aerial mycelium at margin.

Ca-agar: Yellowish wrinkled coherent growth with white aerial mycelium on apices and at margin.

Coon's agar: Colorless mostly submerged growth, scant white aerial mycelium.

Dorset's egg medium: A few round colorless colonies in 3 days; after 3 weeks, irregular raised pink mass, warted appearance, moderate degree of liquefaction.

Serum agar: Raised, convoluted, slightly pinkish growth.

Inspissated serum: No growth.

Broth: Moderate quantity of flakes and dust-like surface growth.

Synthetic sucrose solution: A few colorless flakes on the surface, lesser bottom growth.

Milk: Yellowish surface growth; solid coagulum in one month; later, partly digested, pale pink growth up the wall of the tube.

Litmus milk: Colorless surface growth, liquid blue; becoming hydrolyzed and decolorized.

Potato plug: Small raised pale pink colonies with white aerial mycelium; after 2 months, plug and liquid discolored, growth dull buff, dry and convoluted at base, round and zonate at top of slant, white aerial mycelium, surface and bottom growth on liquid.

Source: From a case of mycetoma of the chest wall in a South African native.

Habitat: Human infections so far as known.

9. **Nocardia pulmonalis** (Burnett) *comb. nov.* (*Actinomyces pulmonalis* Burnett, Ann. Rept. N. Y. State Vet. Coll., 1909–1910, 167.) From Latin *pulmo*, lung.

Gram-positive mycelium breaking up readily into oval-shaped conidia. Acid-fast, especially in early stages of growth.

Gelatin: Small, whitish, spherical colonies; edges of colony becoming chalky white; limited liquefaction.

Agar: Moist, raised growth in the form of small, spherical colonies.

Glucose agar: Dull, whitish, convoluted growth.

Broth: Delicate, translucent film on surface, becoming corrugated with some whitish, spherical colonies in medium.

Milk: Colonies on the surface of the medium; milk is coagulated in a few days, later digested.

Potato: Luxuriant growth in the form of small, translucent, round colonies; becoming colored lemon-yellow; later, growth becomes convoluted or folded with chalky white aerial mycelium, color of plug brownish.

Non-pathogenic for rabbits and guinea pigs.

Aerobic.

Source: From the lungs of a cow.

Habitat: Bovine infections so far as known.

10. **Nocardia paraffinae** (Jensen) *comb. nov.* (*Proactinomyces paraffinae* Jensen, Proc. Linn. Soc. New So. Wales, *56*, 1931, 362.) From M. L. *paraffina*, paraffine.

In agar media, the organism initially forms an extensive mycelium of long, richly-branching hyphae, 0.4 to 0.5 micron thick. After 5 to 6 days, at room temperature, numerous end branches swell to about double thickness, become more refractive, exhibit fine incisions along their external contours, and divide into oval, spore-like elements, 0.8 to 1.0 by 1.2 to 1.5 microns. This process of division starts at the tips of the swollen branches and proceeds basipetally until most of the hyphae appear divided. Primary septa have not been seen in the hyphae. A similar process of division takes place in liquid media, where also the filaments often fall into fragments of variable length. The spore-like elements, but not the undivided filaments, are markedly acid-fast. The aerial mycelium consists of rather short, straight, not very much branched hyphae, 0.4 to

0.6 micron thick, which never show any differentiation into spores.

Gelatin: No liquefaction.

Sucrose agar: Very scant growth. Thin colorless veil, sometimes with a trace of white aerial mycelium.

Glucose agar: Fair growth. Vegetative mycelium flat, growing into medium; pale ochre-yellow to orange, with raised outgrowths on the surface. Growth of a crumbly consistency. Scant, white, aerial mycelium.

Nutrient agar: Slow but good growth. Vegetative mycelium superficial, somewhat raised, ochre-yellow, hard, but with a loose, smeary surface. Aerial mycelium scant, small white tufts. No pigment.

Potato: Fair growth. Vegetative mycelium granulated, first pale-yellow, later deep ochre-yellow to orange. Scant, white, aerial mycelium. No pigment.

Liquid media (milk, broth, synthetic solutions): Small, round granules of various yellow to orange colors, firm, but can be crushed into a homogeneous smear. In old broth cultures a thick, hard, orange to brownish surface pellicle is formed.

Sucrose not inverted.

Starch not hydrolyzed.

Cellulose is not decomposed.

Nitrates are not reduced to nitrites.

Milk is not coagulated or digested.

Final reaction in glucose NH_4Cl solution, pH 4.6 to 4.4.

All strains show a marked power of utilizing paraffin wax as a source of energy.

Source: Isolated from soil.

Habitat: Soil.

11. **Nocardia minima** (Jensen) *comb. nov.* (*Proactinomyces minimus* Jensen, Proc. Linnean Soc. New So. Wales, *56*, 1931, 365.) From Latin *minimus*, very small.

Filaments and rods: 0.4 to 0.6 by 2 to 10 microns. In older cultures mostly short rods, frequently V, Y, swollen forms, or cocci. Irregularly stained with ordinary dyes, generally show bars and bands. Generally a few cells from cultures are acid-fast, most are not acid-fast. Gram-positive.

Gelatin stab: Filiform, granulated, cream-colored growth. No liquefaction.

Agar: Slow growth, raised, folded, with finely myeloid margins. At first colorless, after 6 to 8 weeks flesh pink or coral pink.

Potato: Growth slow, after 6 to 8 weeks abundant, spreading, much raised, finely wrinkled, coral pink.

Paraffin is utilized.

Optimum temperature 22° to 25° C.

Distinctive characters: Closely resembles *Nocardia corallina* but differs in the much slower growth and the smaller size of the cells.

Source: From soil in Australia.

Habitat: Soil.

12. **Nocardia corallina** (Bergey et al.) *comb. nov.* (*Bacillus mycoides corallinus* Hefferan, Cent. f. Bakt., II Abt., *11*, 1904, 459; *Serratia corallina* Bergey et al., Manual, 1st ed., 1923, 93; *Streptothrix corallinus* Reader, Jour. Path. and Bact., *29*, 1926, 1; *Mycobacterium agreste* Gray and Thornton, Cent. f. Bakt., II Abt., *73*, 1928, 84; *Actinomyces agrestis* Bergey et al., Manual, 3rd ed., 1930, 472; *Proactinomyces agrestis* Jensen, Proc. Linnean Soc. New So. Wales, *56*, 1931, 345; *Proactinomyces corallinus* Jensen, *ibid.*, *57*, 1932, 364.) From Latin *corallinus*, coral red.

Description from Gray and Thornton (*loc. cit.*), Jensen (*loc. cit.*) and Bynoe (Thesis, McGill University, Montreal, 1931).

Branching rods, generally curved, 1 to 1.5 by 3 to 10 microns. In older cultures generally shorter rods and cocci. Non-motile. Not acid-fast. Gram-positive.

Gelatin colonies: Round, convex, smooth, pink, shining, edge filamentous. Deep colonies: Burrs.

Gelatin stab: Nailhead; line of stab arborescent. No liquefaction.

Agar colonies: Round, convex, or umbonate, smooth, pink, shining or matte; border lighter, edge filamentous or with arborescent projections. Deep colonies: Burrs, or lens-shaped, with arborescent projections. In their very early stages colonies consist of branching filamentous rods. As the colony grows, the cells in the interior break up into short rods and cocci which eventually form the mass of the colony. Cells on the outside remain filamentous, giving the colony a burr-like appearance, and often forming long arborescent processes.

Agar slant: Filiform, convex, smooth, pink, shining or matte; arborescent or with projections from undulate border.

Litmus milk: Alkaline. Reddish pellicle.

Glycerol potato: Filiform, raised, dry, wrinkled, yellowish-brown to coral red.

Broth: Usually turbid. Pink scum.

Dorset's egg medium: Filiform, raised, dry, wrinkled, orange.

Loeffler's medium: Similar to growth on Dorset's egg medium, but pink.

Nitrites produced from nitrates.

Acid from glycerol and glucose with some strains. No acid or gas from sucrose, maltose or lactose.

Phenol and m-cresol are utilized. Some strains utilize naphthalene. (Gray and Thornton.) Some strains utilize phenol or m-cresol (Jensen).

Optimum pH 6.8 to 8.0.

Optimum temperature 22° to 25°C.

Distinctive characters: Soil organism forming *Mycobacterium*-like colonies after 2 to 4 days on simple media. Pale pink chromogenesis. Nailhead growth in gelatin stab. Branching rods and short filaments.

Source: Seventy-four strains isolated from soils in Great Britain and Australia.

Habitat: Soil.

13. **Nocardia globerula (Gray)** ***comb. nov.*** **(*Mycobacterium globerulum* Gray,** Proc. Roy. Soc. London, B, *102*, 1928, 265; *Proactinomyces globerulus* Reed, in Manual, 5th ed., 1939, 838.) From Latin *globus*, a sphere.

Description from Gray (*loc. cit.*) and from Bynoe (Thesis, McGill University, Montreal, 1931).

Curved rods and filaments: 1 by 2 to 9 microns, with many coccoid cells, especially in old cultures. Rods and filaments are frequently irregularly swollen. Not acid-fast. Capsules may be present. Gram-positive.

Gelatin: After 19 days surface colonies irregularly round, 1 to 2 mm in diameter, convex, light buff, smooth, shining; edge entire. Deep colonies: Round, with entire edge.

Gelatin stab: After 8 days nailhead, irregularly round, convex, pinkish-white, smooth, shining; line of stab erose.

Agar: After 4 days surface colonies irregularly round, 3 to 5 mm in diameter, convex, white, smooth, shining; edge undulate, erose. After 7 days, more convex and of a watery appearance. Deep colonies: After 4 days, lens-shaped.

Agar slant: After 3 days, filiform, flat, watery; edge irregular.

Nutrient and peptone broth: Turbid with viscous suspension.

Indole not formed.

Litmus milk: Alkaline.

Glycerol potato: After 24 hours, filiform, moist, smooth, pale pink.

Dorset's egg medium: After 2 weeks, spreading, raised, moist, orange-colored.

Loeffler's medium: Growth as on Dorset's egg medium, but salmon-colored.

Nitrites not produced from nitrates.

No acid from glucose, lactose, maltose, sucrose or glycerol.

Phenol is utilized.

Indole agar: Blue crystals of indigotin formed.

Optimum temperature 25° to 28°C.

Optimum pH 6.8 to 7.6.

Distinctive characters: This organism resembles most closely *Nocardia corallina*. It is distinguished by pro-

ducing a more watery type of surface growth, more nearly entire deep colonies and more particularly by the production of indigotin from indol.

Source: From soil in Great Britain.

Habitat: Presumably soil.

14. **Nocardia salmonicolor** (den Dooren de Jong) *comb. nov.* (*Mycobacterium salmonicolor* den Dooren de Jong, Cent. f. Bakt., II Abt., *71*, 1927, 216; *Flavobacterium salmonicolor* Bergey et al., Manual, 3rd ed., 1930, 157; *Proactinomyces salmonicolor* Jensen, Proc. Linnean Soc. New So. Wales, *57*, 1932, 368.) From Latin *salmo*, salmon and *color*, color.

Closely related to *Nocardia corallina*.

On glucose-asparagine-agar after 18 to 24 hrs., long branching rods are formed, 1.0 to 1.3 microns in thickness, with small refractive granules of aerial mycelium, sometimes stretching into quite long filaments; after 2 to 3 days small definite mycelia are present, and after 5 to 6 days these have largely divided into short rods and cocci; the colonies have the same burr-like appearance as those of *Nocardia corallina*. Many cells at the edge of the colonies show, after 3 to 4 days, club- or pear-shaped swellings, up to 2.5 to 3.0 microns in width; after 5 to 6 days, many of these swollen cells are seen to germinate with the formation of two more slender sprouts. (Ørskov, Investigations into the Morphology of the ray fungi. Copenhagen, 1923, 82, gives an almost identical picture of *Streptothrix rubra;* it is questionable, indeed, whether these two organisms are not really identical.)

Gelatin: At 20° to 22°C, scant arborescent growth in stab; small wrinkled orange surface colony. No liquefaction.

Glucose-asparagine-agar: Good growth, restricted, rather flat, edges lobate, surface warty, glistening, first pale orange, later ochre-yellow; consistency crumbly. After 5 to 6 weeks the growth is paler with many small round raised yellow secondary colonies.

Glucose-nutrient agar: Excellent growth, spreading, flat, dense, edges lobate, surface folded, glistening, yellow, gradually changing to deep orange-red.

Nutrient broth: Fair growth; thin pellicle and granular sediment, at first cream-colored, later red; broth clear at first, slightly turbid after 3 weeks.

Milk: Good growth; pellicle of small cream-colored granules after 2 days, later a thick orange sediment. Not coagulated, but appears slightly cleared after 5 weeks, the reaction becoming alkaline.

Potato. Good growth, raised, warty, crumbly, glistening, at first buff, changing to orange and finally to almost blood-red.

Indole not formed.

Nitrites produced from nitrates.

Nitrate, ammonium salts, asparagine and peptone are utilized almost equally well with glucose as source of carbon, although the growth is most rapid with peptone.

Sucrose not inverted, although readily utilized with sodium nitrate as a source of nitrogen.

Paraffin readily utilized as a source of carbon.

Phenol not utilized.

No acid from glucose or glycerol.

Starch not hydrolyzed.

No growth in oxygen-free atmosphere.

Source: Isolated from soil by means of an ethylamine enriched medium, at 37°C.

Habitat: Probably soil.

15. **Nocardia rubropertincta** (Hefferan) *comb. nov.* (Butterbacillus, Grassberger, Münch. med. Wochnschr., *46*, 1899, 343; *Bacillus rubropertinctus* Hefferan, Cent. f. Bakt., II Abt., *11*, 1903, 460; *Serratia rubropertinctus* Bergey et al., Manual, 1st ed., 1923, 96; *Mycobacterium rubropertinctum* Ford, Textb. of Bact., 1927, 255; *Proactinomyces rubropertinctus* Reed, in Manual, 5th ed.,

1939, 835.) From Latin, colored very red.

Büttner (Arch. Hyg., *97*, 1926, 17) regards *Mycobacterium eos* as probably identical with *Mycobacterium rubrum* Söhngen (Cent. f. Bakt., II Abt., *37*, 1913, 599), Grassberger's organism (*loc. cit.*), Hormann and Morgenrot's organism (Hyg. Rundsch., *7*, 1898, 229), and Weber's organism (Arb. a. d. k. Gesundheitsamte, Berlin, *19*, 1903).

To this list Lehmann and Neumann (Bakt. Diag., 7 Aufl., *2*, 1927, 764) also add the organism of Ascher (Ztschr. f. Hyg., *32*, 1899, 329) and the butter bacillus of Aujeszky (Cent. f. Bakt., I Abt., Orig., *31*, 1902, 132).

Jensen (Proc. Linnean Soc. New So. Wales, *49*, 1934, 32) regards the following organisms as probably identical: *Bacterium rubrum* Migula (Syst. d. Bakt., *2*, 1900, 488) a preliminary description of which is given by Schneider (Arb. bakt. Inst. Karlsruhe, *1*, Heft 2, 1894, 213); probably this is also the organism referred to by Haag (Cent. f. Bakt., II Abt., *71*, 1927, 35) as *Bacterium rubrum*; and *Mycobacterium rubrum* Söhngen (*loc. cit.*).

Description taken from Grassberger (*loc. cit.*), Hefferan (*loc. cit.*) and Jensen (*loc. cit.*).

Small rods: 0.3 to 0.9 by 1.5 to 3.0 microns. Cells in 18 to 24 hour agar culture in beautiful angular arrangement, after 2 to 3 days nearly coccoid, 0.6 by 0.8 micron. Tendency for branching on glycerol agar after 2 to 3 days, but branching does not occur commonly though granules of aerial mycelium are sometimes seen (Jensen). Not acid-fast (Grassberger). Acid-fast (Hefferan). Variable (Jensen). Non-motile. Gram-positive.

Gelatin colonies: Irregular with crenate margin and folded surface. Coral red.

Gelatin stab: Surface growth like the colonies. Growth in stab at first thin, then granular to arborescent with chromogenesis. No liquefaction.

Agar colonies: Small, granular, becoming pink to red depending on composition of agar.

Agar slant: Dry, lustreless (R) to glistening (S), pink to vermillion red.

Broth: Faint uniform turbidity with salmon-pink pellicle (in scales) which is renewed on surface as it settles to form a red sediment (Hefferan, Jensen).

Litmus milk: Thick, fragile, dull coral red surface scales and sediment. Unchanged (Hefferan) to alkaline and somewhat viscid after 3 to 4 weeks (Jensen).

Potato: Slow but excellent intensive red growth becoming dull orange (Jensen).

Nitrites not produced from nitrates; nitrates, ammonia and asparagine are almost as good sources of nitrogen as peptone (Jensen).

Benzine, petroleum, paraffin oil and paraffin are utilized as sources of energy (Söhngen). No action on manganese dioxide (Söhngen, Cent. f. Bakt., II Abt., *40*, 1914, 554).

Optimum pH 6.8 to 7.2. Growth stops at pH 4.9.

Temperature relations: Grows well between 20° and 37°C (Jensen).

Aerobic to facultative anaerobe.

Distinctive characters: *Mycobacterium*-like colonies with coral to vermillion red chromogenesis on asparagine agar, potato, gelatin and other media. Short rods, seldom forms filaments. Generally not acid-fast.

Source: Six cultures isolated from butter (Grassberger). Several cultures isolated from soil in Holland (Söhngen) and Australia (Jensen). Two cultures as contaminants in tuberculin flasks (Hagan, Breed).

Habitat: Probably widely distributed in soil.

16. **Nocardia rubra** (Krassilnikov) *comb. nov.* (*Proactinomyces ruber* Krassilnikov, Bull. Acad. Sci. U. S. S. R., No. 1, 1938, 139.) From Latin *ruber*, red.

Mycelium produced at first but soon breaks up into rods and cocci. The latter multiply by fission, cross-wall formation and budding. Cells are Gram-positive, weakly acid-fast.

Gelatin: No liquefaction.

Colonies smooth or folded and rough, shiny or dull, dark red color. Pigment belongs to the carotinoids, does not diffuse into the medium.

Milk: No coagulation or peptonization.

Sucrose not inverted.

Starch not hydrolyzed.

No growth on cellulose.

Readily assimilates fats and paraffin, and, to a less extent, wax.

Various strains of this organism may vary considerably from type.

Habitat: Soil.

17. **Nocardia coeliaca** (Gray and Thornton) *comb. nov.* (*Mycobacterium coeliacum* Gray and Thornton, Cent. f. Bakt., II Abt., *73*, 1928, 88; *Flavobacterium coeliacum* Bergey et al., Manual, 3rd ed., 1930, 156; *Proactinomyces coeliacus* Reed, in Manual, 5th ed., 1939, 836.)

Description from Gray and Thornton (*loc. cit.*) and from Jensen (Proc. Linnean Soc. New So. Wales, *56*, 1931, 201).

Short, curved, uneven-sided rods: 0.8 by 5 microns with occasional filaments up to 10 to 12 microns long, frequently beaded, occasionally swollen or branched. Coccoid forms 0.8 to 1.2 microns in diameter are common, especially in older cultures. Stain readily. Not acid-fast or occasionally slightly acid-fast. Gram-positive.

Gelatin colonies: After 12 days, irregular, raised, white, rugose, dull, edge entire. Deep colonies: Irregular, smooth or slightly broken.

Gelatin stab: Convoluted, buff-white to yellowish, dull; below surface the growth forms many irregular hollow lobes, giving a glistening appearance, to a depth of 3 to 4 mm.

Agar colonies: After 11 days, less than 1 mm in diameter, round or irregular, raised, white, resinous, edge irregular, burred. Deep colonies: Irregularly round or oval, edge slightly broken.

Agar slant: Filiform, convex, white, rugose, resinous, edge undulate.

Broth: Turbid.

Litmus milk: Slightly alkaline after 5 to 7 days.

Glycerol potato: After 2 days, dry, crumpled, orange, becoming brown after about 10 days.

Dorset's egg medium: Raised, smooth, moist, verrucose, buff-colored.

Loeffler's medium: After 10 days, slight growth, dry, granular, pale buff-colored.

Nitrites are not produced from nitrates.

No acid from glucose, lactose, sucrose or glycerol.

Phenol is utilized.

Optimum pH 7.6 to 8.0.

Optimum temperature 22° to 25°C.

Distinctive characters: Differs from the previously described members of the genus in the absence of chromogenesis. Forms hollow lobes in deep gelatin cultures. Cells are rods, seldom filaments.

Source: From soil in Great Britain and Australia.

Habitat: Presumably soil.

18. **Nocardia transvalensis** Pijper and Pullinger. (Pijper and Pullinger, Jour. Trop. Med. Hyg., *30*, 1927, 153; *Actinomyces transvalensis* Nannizzi, in Pollacci, Tratt. Micopat. Umana, *4*, 1934, 46.) Named for the Transvaal, a state of South Africa.

Description from Erikson (Med. Res. Council Spec. Rept. Ser. 203, 1935, 28).

Initial mycelium unicellular, but with the central branch frequently broader and showing dense granular refractile contents, small colonies quickly covered with aerial mycelium, the straight aerial hyphae in some cases becoming clustered into irregular spikes, colorless drops are exuded and a pink coloration produced in

the densest part of the growth on synthetic glycerol agar. Angular branching with division of the substratum filaments can be seen, the aerial hyphae also being irregularly segmented. Acid-fast.

Gelatin: Poor growth, a few irregular colorless flakes. No liquefaction.

Agar: No growth.

Glucose agar: Raised, granular, pink colonies with white aerial mycelium.

Glycerol agar: Small pink coiled masses with thin white aerial mycelium.

Potato agar: No growth.

Coon's agar: Colorless growth with liberal white aerial mycelium.

Dorset's egg medium: Small irregularly raised and coiled dull pink mass.

Serum agar: Very poor growth.

Inspissated serum: Scant colorless flaky growth; later a minute tuft of pale pink aerial mycelium.

Broth: Moderate flaky growth.

Synthetic sucrose solution: Poor growth, a few flakes on surface, a few at bottom.

Potato plug: Dry, raised, convoluted, pink growth with white aerial mycelium in one month; dull, pink, brittle surface colonies, with paler aerial mycelium floating coherently on liquid at base in 2 months.

Milk: No change.

Starch not hydrolyzed.

Source: From a case of mycetoma of the foot in South Africa.

Habitat: Human infections so far as known.

19. **Nocardia mesenterica** (Orla-Jensen) *comb. nov.* (*Microbacterium mesentericum* Orla-Jensen, The Lactic Acid Bacteria, 1919, 181; *Proactinomyces mesentericus* Jensen, Proc. Linnean Soc. New So. Wales, *57*, 1932, 373.) From Greek *mesenterium*, mesentery.

Extensive mycelium composed of richly branching hyphae of a somewhat variable thickness, 0.4 to 0.8 micron; no aerial hyphae are seen. With increasing age the hyphae divide into fragments of varying size and shape, partly diphtheroid rods, but no real cocci. There is, particularly in richer media, a tendency to form large, swollen, fusiform to almost spherical cells, up to 3.5 microns in diameter. These may stain intensely with carbol fuchsin; when transferred to fresh media, they germinate and produce a new mycelium.

Gelatin: Good growth; finely arborescent, cream-colored growth in the stab; raised, folded, pale-yellow, surface colony. No liquefaction.

Glucose-asparagine-agar: Fair growth, narrow, raised, granular, very pale yellow, glistening; condensation water clear, with small granules. At 30°C only scant growth consisting of small irregular white granules, growing deeply down into the agar.

Glucose-nutrient-agar: Good growth, restricted, with undulate edges, surface with high transverse folds, cream-colored; the consistency is firm and cartilaginous after 2 days, later looser and more brittle. Growth at 28° to 30°C rather scant; smooth, soft, glistening, cream-colored smear.

Sabouraud's agar: Excellent growth, spreading, at first flat and smooth, pale straw-yellow, perfectly hard and cartilaginous, later raised and strongly folded, of a loose, curd-like consistency, bright lemon-yellow. Growth at 28° to 30°C only fair, restricted, folded, cream-colored, soon becoming soft and smeary.

Potato: Scant growth; restricted, soft, cream-colored smear.

Broth: Good growth; voluminous, flaky, whitish sediment; broth clear.

Milk: At 28° to 30°C, small cream-colored granules along the tube; the milk undergoes no visible changes within 4 weeks. No proteolytic action.

Indole not formed.

Sucrose is inverted.

Starch is hydrolyzed.

Cellulose is not decomposed.

Nitrates are reduced to nitrites.

No growth in oxygen-free atmosphere.

Nitrogen is utilized as sodium nitrate, ammonium phosphate and asparagine, although these are inferior to peptone as sources of nitrogen.

Source: Fermented beets.

20. **Nocardia flava** (Krassilnikov) *comb. nov.* (*Proactinomyces flavus* Krassilnikov, Bull. Acad. Sci. U. S. S. R., No. 1, 1938, 139.) From Latin *flavus*, yellow.

Cells at first filamentous, 0.7 to 0.8 micron in diameter; after 2 to 3 days broken into long rods and then into cocci 0.7 micron in diameter. No spores, some strains form chlamydospores. Cell multiplication by fission, cross-wall formation, rarely by budding. Cells Gram-positive; not acid-fast.

Gelatin: No liquefaction.

Synthetic agar colonies: Bright yellow or gold color.

Meat peptone media: Dirty yellow pigmentation.

Agar colonies: Pigment bright yellow or gold color on synthetic media, dirty yellow on meat peptone media. Pigment not soluble in medium. Surface of colony somewhat shiny or rough and folded, of a dough-like consistency.

Milk: No peptonization or coagulation.

Sucrose weakly inverted.

Starch is hydrolyzed.

Does not grow on paraffin and wax but makes weak growth on fat.

Habitat: Soil, not common.

21. **Nocardia viridis** (Krassilnikov) *comb. nov.* (*Proactinomyces viridis* Krassilnikov, Bull. Acad. Sci. U. S. S. R., No. 1, 1938, 139). From Latin *viridis*, green.

Mycelial cells often branching, 0.7 to 0.8 micron in diameter with cross-wall; after 5 to 7 days the cells break up into rods 5 to 15 microns long. Cocci not observed. Cells multiply by fission, seldom by budding. Spores not formed. Cells Gram-positive, not acid-fast.

Gelatin: No liquefaction.

Colonies colored dark green. Pigment not soluble in medium, in water or in organic solvents. Surface of colony somewhat shiny. On potato, rough, much folded, broken up into small colonies.

Milk: No peptonization or coagulation.

Sucrose readily inverted.

Starch weakly hydrolyzed.

Grows well on fats and paraffin and less on wax.

Habitat: Soil.

22. **Nocardia citrea** (Krassilnikov) *comb. nov.* (*Proactinomyces citreus* Krassilnikov, Bull. Acad. Sci. U. S. S. R., No. 1, 1938, 139.) From M. L. *citreus*, lemon yellow.

Mycelium in young cultures consists of very fine threads 0.3 to 0.5 micron in diameter. After several days the cells break up into short rods 0.5 by 1.5 to 5 microns and into cocci 0.3 to 0.5 micron in diameter. Multiplies by fission and bud formation; spores not formed. Cells not acid-fast.

Gelatin: Liquefaction.

Colonies: Yellow-green, usually rough and folded.

Milk: Coagulation and peptonization.

Sucrose is inverted.

Starch is hydrolyzed.

Weak growth on fat. No growth on paraffin or wax.

Habitat: Soil and water.

23. **Nocardia madurae** (Vincent) Blanchard. (*Streptothrix madurae* Vincent, Ann. Inst. Past., *8*, 1894, 129; Blanchard, Bouchard's Traité de Path. Gén., *2*, 1896, 868; *Oospora madurae* Lehmann and Neumann, Bakt. Diag., 1 Aufl., *2*, 1896, 388; *Actinomyces madurae* Lachner-Sandoval, Ueber Strahlenpilze, 1898, 64; *Cladothrix madurae* Macé, Traité Pratique de Bact., 4th.ed., 1901, 1090; *Discomyces madurae* Gedoelst, Champ. Paras. Homme et Animaux, Paris. 1902. 169.) Named for the disease

Madura foot, with which this organism is associated.

Oospora indica Kanthack (Kanthack, Jour. Path. and Bact., *1*, 1893, 140; *Nocardia indica* Chalmers and Christopherson, Ann. Trop. Med. and Parasit., *10*, 1916, 231; *Discomyces indicus* Neveu-Lemaire, Précis de Parasitol. Hum., 5th ed., 1921, 42; *Actinomyces indicus* Brumpt, Précis de Parasitol., Paris, 4th ed., 1927, 1196) is regarded by some authors as identical with *Nocardia madurae* Blanchard. If this is established, then the correct name of the organism is *Nocardia indica* (Kanthack) Chalmers and Christopherson.

The species described under the name *Actinomyces madurae* in previous editions of Bergey's Manual is definitely not the true causative agent of the disease and is probably a contaminant carried as a culture of this species.

Morphology in tissues, growth in form of granules consisting of radiating actinomycosis. In cultures, initial branched mycelium fragmenting into rod-shaped and coccoid bodies. No aerial mycelium or spores. Not acid-fast.

Gelatin: Growth scant, whitish; no liquefaction.

Gelatin colonies: Round, glistening, at first white, then buff to rose or crimson. Pigment production is irregular and unpredictable. Occasionally red soluble pigment is produced. Growth eventually wrinkled. No aerial mycelium.

Potato: Wrinkled friable growth; buff-colored, sometimes red.

Broth: Growth as a floccular sediment.

Milk: No change, or slight slow peptonization.

Diastatic (?) action.

Not pathogenic for the usual laboratory animals; pathogenic for monkeys (Musgrave and Clegg, Philippine Jour. Sci., Ser. B., Med. Sci., *3*, 1908, 470).

Habitat: Cause of some cases of Madura foot.

24. **Nocardia lutea** Christopherson and Archibald. (Christopherson and Archibald, Lancet, *2*, 1918, 847; *Actinomyces luteus* Brumpt, Précis de Parasitol., Paris, 4th ed., 1927, 1206.) From Latin *luteus*, yellow.

Description from Erikson (Med. Res. Council Spec. Rept. Ser. 203, 1935, 30).

Initial elements swollen and segmented, giving rise to irregular spreading polymorphous colonies composed of cells of all shapes and sizes with markedly granular contents. Later more monomorphous, the filaments being arranged in angular apposition. Sometimes (e.g., on synthetic glycerol agar) the segments are so granular as to appear banded. On potato agar, small filamentous colonies are formed with irregular angular branching and bear a few isolated short straight aerial hyphae.

Gelatin: Pale pink wrinkled growth on wall of tube and colorless punctiform and stellate colonies in medium; no liquefaction.

Agar: Abundant, coherent, moist, pink membranous growth with round discrete colonies at margin; after 3 weeks colorless fringed margin, round confluent portion.

Glucose agar: Scant reddish smeary growth.

Glycerol agar: Yellowish-pink, wrinkled membrane.

Potato agar: Coherent pink moist growth, centrally embedded with small round discrete colonies at margin.

Dorset's egg medium: Poor growth, dull pink, spreading.

Serum agar: Confluent granular pink membrane.

Broth: Pink flakes and surface growth.

Inspissated serum: Raised convoluted pink mass; becoming orange, much wrinkled, scalloped margin.

Synthetic sucrose solution: Red granules and abundant minute colorless colonies at bottom; in 2 weeks a colorless dust-like surface pellicle.

Glucose broth: Abundant, pinkish

flaky surface growth, breaking up easily and sinking to bottom.

Litmus milk: Orange-red surface and bottom growth, liquid blue.

Potato plug: Carrot-red, moist, thick, granular growth in bands, partly raised and with discrete round colonies; sparse colorless very thin aerial mycelium at top of slant in 2 months.

Source: From actinomycosis of the lachrymal gland.

25. **Nocardia blackwellii** (Erikson) *comb. nov.* (*Actinomyces blackwellii* Erikson, Med. Res. Counc. Spec. Rept. Ser. 203, 1935, 37.)

Description from Erikson (*loc. cit.*, p. 32).

Initial elements short, rod-like, growing out into longer forms sparsely branching; small radiating colonies are produced with short straight aerial mycelium, frequently large round or ovoid cells are interposed in the irregularly segmented chains of cells, being sometimes isolated in company with 2 or 3 short filaments and sometimes terminal.

Gelatin: Few colorless minute colonies along line of inoculation; after 30 days abundant colorless colonies to 10 mm below surface, larger pink-yellow surface colonies with white aerial mycelium; no liquefaction.

Agar: Confluent wrinkled growth with small, round, pinkish, discrete colonies at margin.

Glucose agar: Abundant, pale pink growth, small conical colonies, piled up, convoluted.

Glycerol agar: Extensive, granular, irregular, thin, pinkish growth; after 40 days, a few discrete colonies with depressed margins, center piled up, pink.

Serum agar: Smooth, cream, umbilicated colonies, with submerged growth extending into medium in scallops 5 to 8 mm deep; a pale pink mass in 2 weeks.

Potato agar: Small, round, colorless colonies covered with white aerial mycelium; after 2 weeks colonies dull pink, submerged margins, few aerial spikes, moderate aerial mycelium at top of slant.

Broth: Flakes, later innumerable minute colonies, some adhering to wall just above liquid level.

Synthetic sucrose solution: Delicate, round, white colonies; later abundant minute colonies in suspension, thick cream pellicle on surface and pink grains in sediment.

Milk: Heavy convoluted bright yellow surface pellicle, no coagulation.

Litmus milk: Yellow surface growth, milky sediment, liquid unchanged.

Carrot plug: Small, round, smooth, cream-colored elevated colonies in 10 days; sparse stiff colorless aerial spikes in 16 days; abundantly piled up, convoluted, ochreous growth in 25 days.

Source: From hock joint of foal.

26. **Nocardia cuniculi** Snijders. (Snijders, Geneesk. Tijdsch. Med. Ind., *64*, 1924, 47 and 75; *Actinomyces cuniculi* Erikson, Med. Res. Council Spec. Rept. Ser. 203, 1935, 32; not *Actinomyces cuniculi* Gasperini, Cent. f. Bakt., *15*, 1894, 684; *Actinomyces sumatrae* Erikson, *loc. cit.*, 32.) From Latin *cuniculus*, rabbit.

Description taken from Erikson (*loc. cit.*, p. 31).

Large swollen cells give rise to ramifying filaments or to small chains of short thick segments which branch out into more regular hyphae; sometimes the irregular elements are beset with spiny processes before giving rise to typical long branching filaments; later the picture becomes more monomorphous and short straight aerial hyphae are borne, which presently exhibit irregular segmentation.

Gelatin: Few flakes. No liquefaction.

Agar: Small, round, elevated, cream-colored colonies, umbilicated and radially wrinkled.

Glucose agar: Minute, colorless colon-

ies; becoming dull pink, partly confluent and piled up, few stiff pink aerial spikes.

Glycerol agar: Small round elevated cream-colored colonies, margins depressed; becoming smooth, discrete, yellowish.

Dorset's egg medium: Scant pinkish smeary growth.

Serum agar: Small, raised, cream-colored colonies, becoming confluent and piled up.

Inspissated serum: Thick, colorless, ribbed membrane; no liquefaction.

Broth: Small and larger cream-colored, scale-like surface colonies, abundant, flocculent bottom growth.

Synthetic sucrose solution; Thin surface pellicle, small colorless flakes, minute particles at bottom, scant growth.

Milk: Heavy yellow growth attached to walls; solid coagulum in 1 month.

Litmus milk: Yellow surface growth, liquid unchanged.

Potato plug: Coral-pink, dry, granular growth, covered to a considerable extent with white aerial mycelium, piled up in center, discrete colonies at margin, pink surface pellicle on liquid and colorless colonies at base.

Source: Infected rabbits.

27. **Nocardia rangoonensis** (Erikson) *comb. nov.* (*Actinomyces rangoon* Erikson, Med. Res. Council Spec. Rept. Ser. 203, 1935, 37.)

Description from Erikson (*loc. cit.*, p. 33).

Swollen round initial cells, giving rise to branching hyphae which segment and present slipping and angular arrangement; few short straight aerial hyphae, which later develop into a profusely branching long waving aerial mycelium. Non-acid-fast.

Gelatin: Abundant minute colonies in depths and larger cream-colored ones on surface with white aerial mycelium; brown pigment surrounding growth. No liquefaction.

Agar colonies: Round, lobate, umbilicated, raised up, cream-colored to pale pink; later, medium discolored dark brown, colonies colorless.

Glucose agar: Convoluted, coherent, cream-colored growth, medium discolored. After 23 days, wrinkled, biscuit-colored growth, colorless margin, border white aerial mycelium, medium dark brown.

Glycerol agar: Dull, mealy, pink, wrinkled growth, scant white aerial mycelium at top, medium slightly discolored.

Coon's agar: Minute colorless colonies in streaks.

Potato agar: Small, round, lemon-colored colonies, partly confluent, with white aerial mycelium; later medium discolored light brown; submerged growth greenish.

Dorset's egg medium: Extensive colorless growth, pale pink aerial mycelium in center; later covered with a powdery pinkish-white aerial mycelium.

Serum agar colonies: Irregular, small, elevated, cream-colored, frequently umbilicated.

Inspissated serum: Poor growth, small piled up pink mass.

Broth: Abundant colorless growth, flocculent mass at bottom and pellicle at surface, medium slightly discolored.

Synthetic sucrose solution: Small white colonies with pinkish tinge on surface, lesser bottom growth.

Milk: Coagulation, yellow surface ring, becoming partly peptonized, liquid discolored dark brown, brownish growth up side of tube.

Litmus milk: Colorless growth, liquid partly decolorized; coagulation; later partly digested.

Carrot plug: Small round colorless colonies, velvety white aerial mycelium; in 2 months, piled up pink granular mass with warted prominences, marginal zone white aerial mycelium and thin all-over central aerial mycelium.

Source: Human pulmonary case of streptothricosis.

Habitat: Human infections so far as known.

28. **Nocardia caviae** Snijders. (Snidjers, Geneesk. Tijdschr. Ned. Ind., *64*, 1924, 47 and 75; *Actinomyces caviae* Erikson, Med. Res. Council Spec. Rept. Ser. 203, 1935, 37.) From the generic name of the guinea pig.

Description from Erikson (*loc. cit.*, p. 32).

Initial segmentation, producing elements of approximately even thickness arranged in angular apposition, and later long profusely ramifying threads with strongly refractile protoplasm. Aerial mycelium straight and branching, the aerial hyphae with occasional coiled tips divided into cylindrical conidia.

Gelatin: A few colorless flakes. No liquefaction.

Glucose agar: Piled up, convoluted, cream-colored to pale pink growth, white aerial mycelium.

Glycerol agar: Scanty growth.

Coon's agar: Colorless scant growth, partly submerged, white aerial mycelium.

Potato agar: Colorless spreading growth with dense white aerial mycelium.

Dorset's egg medium: Heavily corrugated pale pink growth with submerged margin, dense white aerial mycelium in center; after 3 weeks, colorless transpired drops.

Serum agar: Pale pink wrinkled growth, partly submerged; after 4 weeks, piled up with scant white aerial mycelium, medium discolored reddish-brown.

Inspissated serum: Pale pink raised growth, coiled, white aerial mycelium.

Broth: Cream-colored wrinkled surface pellicle extending up wall and breaking easily, moderate bottom growth, flaky, medium discolored.

Synthetic sucrose solution: Round white colonies in suspension and attached to one side of tube, pink surface colonies with white aerial mycelium.

Milk: Colorless surface growth, white aerial mycelium; coagulation.

Litmus milk: Liquid blue, surface growth; after 1 month, white aerial mycelium, colorless sediment, liquid still blue.

Potato plug: Small colorless colonies, white powdery aerial mycelium; later abundant raised pale pink confluent growth, discolored plug; after 2 months, raised buckled pink colonies with white aerial mycelium floating on liquid at base.

Source: Infected guinea pigs, Sumatra.

29. **Nocardia actinomorpha** (Gray and Thornton) *comb. nov.* (*Mycobacterium actinomorphum* Gray and Thornton, Cent. f. Bakt., II Abt., *73*, 1928, 88; *Actinomyces actinomorphus* Bergey et al., Manual, 3rd ed., 1930, 471; *Proactinomyces actinomorphus* Jensen, Proc. Linnean Soc. New So. Wales, *56*, 1931, 363.) From Greek *actis*, ray and Latin *morpha*, shape, form.

Description from Gray and Thornton (*loc. cit.*), Jensen (*loc. cit.*), and Bynoe (Thesis, McGill University, Montreal, 1931).

Long branching filaments and rods: 0.5 to 0.8 by up to 10 microns. In older cultures rods 2 to 3 microns long generally predominate. On some media extentively branching hyphae occur. Readily stained. Not acid-fast. Gram-positive.

Gelatin colonies: After 12 days, round, saucer-like, white, raised rim, edges burred. Liquefaction. Deep colonies: Burrs.

Gelatin stab: After 8 to 14 days, saccate liquefaction, 5 to 8 mm.

Agar colonies: After 11 days, round, 1 mm in diameter, convex, white, granular or resinous; long arborescent processes from the edge. Deep colonies: Arborescent burrs; processes about equal to diameter of colony.

Agar slant: Filiform, raised to convex, white, rugose, dull; edge undulate, with strong tufted projections below surface.

Broth: Turbid, or clear with white scum.

Dorset's egg medium: After 2 weeks, raised, dry, smooth, salmon-buff growth.

Loeffler's medium: After 2 days, smooth, moist, warty, salmon-colored growth.

Litmus milk: Alkaline after 5 to 7 days.

Glycerol potato: After 2 days, dry, wrinkled, pink to orange growth.

Nitrites are produced from nitrates.

No acid from glucose, lactose, sucrose or glycerol.

Phenol and naphthalene are utilized.

Optimum temperature 25° to 30°C.

Optimum pH 7.8 to 8.5.

Distinctive characters: Differs from *Nocardia coeliaca* in saccate liquefaction of gelatin. Long rods and filaments.

Source: A few strains have been isolated from soil in Great Britain and Australia.

Habitat: Presumably soil.

30. **Nocardia flavescens** (Jensen) *comb. nov.* (*Proactinomyces flavescens* Jensen, Proc. Linnean Soc. New So. Wales, *56*, 1931, 361.) From Latin *flavescens*, becoming golden yellow.

On media where a firm growth is produced, the vegetative mycelium appears as long, branched, non-septate hyphae, 0.4 to 0.6 micron thick. In other media, as on nutrient agar and potato, septa are formed and the mycelium appears in preparations as fragments of very variable size, partly resembling highly branched mycobacteria. In several cases—for instance, on nutrient agar at 28° to 30°C, in 5 to 6 weeks old cultures in glucose broth, and in glucose NH_4Cl solution—short elements assume swollen, fusiform to lemon-shaped forms. The aerial mycelium consists of fairly long hyphae of the same thickness as the vegetative hyphae, not very much branched, without spirals, often clinging together in wisps. A differentiation into spores is never visible by direct microscopic examination. Neither is this the case in stained preparations; here the aerial hyphae break up into fragments of quite variable length, from 1.2 to 1.5 up to 10 to 12 microns, showing an irregular, granulated staining.

Gelatin: Slow liquefaction.

Sucrose agar: Good growth. Vegetative mycelium superficially spreading, much raised and wrinkled, cracking, white to cream-colored, of a dry, but loose and crumbly, consistency. Aerial mycelium scant, thin, white. Faint yellow soluble pigment after 2 to 3 weeks.

Glucose agar: Good growth. Vegetative mycelium superficial, wrinkled, honey-yellow, of a hard and cartilaginous consistency. Aerial mycelium thin, smooth, white. Yellow soluble pigment.

Nutrient agar: Good growth. Vegetative mycelium raised and much wrinkled, first dirty cream-colored, later dark yellowish-gray, of a soft, moist, curd-like consistency. No aerial mycelium. No pigment.

Potato: Good to excellent growth. Vegetative mycelium much raised and wrinkled, first cream-colored, later yellowish-brown, soft and smeary. No aerial mycelium, no pigment.

Glucose broth: Rather scant growth. Granulated, yellowish sediment; no surface growth. Broth clear. No pigment. No acidity.

Sucrose is inverted.

Starch is hydrolyzed.

Cellulose is not decomposed.

Nitrates are reduced slightly or not at all with various sources of energy.

Milk: Coagulated and slowly redissolved with acid reaction.

Final reaction in glucose-NH_4Cl solution, pH 3.9 to 3.6.

No growth under anaerobic conditions.

Habitat: Soil.

31. **Nocardia maculata** (Millard and Burr) *comb. nov.* (*Actinomyces maculatus* Millard and Burr, Ann. Appl. Biol., *13*, 1926, 580; *Proactinomyces maculatus* Umbreit, Jour. Bact., *38*, 1939, 84.) From Latin *maculatus*, spotted.

Description taken from Umbreit.

Filamentous organisms possessing a tough shiny colony which is cartilaginous, rarely producing an aerial mycelium, though in certain strains, it may occur frequently. Retains the mycelium form for long periods. Not acid-fast.

Gelatin: Liquefaction.

In the young colony an orange-yellow to orange-red intercellular pigment is produced on all media, which may or may not change to black as the culture ages.

Milk: No digestion.

Starch is hydrolyzed.

Does not utilize paraffin.

Habitat: Soil.

32. **Nocardia rhodnii** (Erikson) *comb. nov.* (*Actinomyces rhodnii* Erikson, Med. Res. Council Spec. Rept. Ser. 203, 1935, 37.) Named for the insect genus, *Rhodnius*.

Description from Erikson (*loc. cit.*, p. 29).

In early stages, the minute colonies are composed of hyphal segments arranged in angular apposition; the aerial mycelium being short and straight. Later the growth becomes extensive and spreading, made up partly of long, genuinely branching filaments and partly of short segments exhibiting slipping branching, each giving rise to aerial hyphae. After 2 weeks the angular branching is very marked, delicate spreading herring-bone patterns being formed.

Gelatin: Rapid liquefaction; pale pink colonies in superficial pellicle and sediment.

Coon's agar: Colorless pinpoint colonies.

Czapek's agar: Minute, colorless, round colonies.

Glucose agar: Abundant, coral pink, convoluted, piled up growth.

Glycerol agar: Extensive growth, dull pink colonies round and umbilicated, becoming piled up and deeper coral; later partly submerged.

Dorset's egg medium: Salmon-pink, granular membrane; later piled up.

Serum agar: Extensive, reddish, confluent mass, granular, tending to be piled up; the medium around the growth shows reddish coloration in 2 weeks.

Inspissated serum: Smooth, round, pale pink colonies, centrally depressed and irregularly coiled larger mass; no liquefaction.

Broth: Salmon-pink flakes in sediment and colonies on surface; after 2 weeks abundant growth, discoloration of medium.

Glucose broth: Thin, pink, superficial pellicle, easily breaking up, and small flakes in sediment; after 2 weeks abundant growth extending up tube.

Synthetic sucrose solution: Colorless to pink colonies in superficial pellicle, and minute round white colonies coherent in loosely branching mass in sediment.

Milk: Bright orange growth; medium unchanged.

Potato agar: Abundant, pink growth, piled up, scant stiff white aerial mycelium at top of slant.

Source: From reduvid bug, *Rhodnius prolixus*.

33. **Nocardia gardneri** (Waksman) *comb. nov.* (Actinomycete, Gardner and Chain, Brit. Jour. Exp. Path., *23*, 1942, 123; *Proactinomyces gardneri* Waksman, in Waksman, Horning, Welsch and Woodruff, Soil Sci., *54*, 1942, 289.) Named for Prof. Gardner who first isolated this organism.

Gram-positive, branching mycelium.

Gelatin: Cream-colored surface ring. Rapid liquefaction. Green to greenish-brown soluble pigment gradually diffuses through the liquefied portion.

Nutrient agar: Cream-colored, elevated, lichenoid growth, soft, not leathery; no aerial mycelium; very faint brownish pigment.

Glucose agar: Brownish, lichenoid

growth, with wide, cream-colored edge; white to grayish aerial mycelium gradually covering surface. Reverse of growth yellowish; no soluble pigment.

Glucose-asparagine agar: Aerial mycelium develops slowly.

Tryptone broth: Growth occurs as small pellets at the base of the flask; later, a thin surface pellicle appears, which consists of a branching mycelium. Black pigment slowly produced.

Litmus milk: Unchanged.

Potato: Barnacle-like, brownish, spreading growth; no aerial mycelium. Medium brownish around growth.

Indole not formed.

No acid from glucose, lactose, maltose, mannitol, sucrose and dulcitol.

Good growth at 25°C. Slow growth at 37°C.

Distinctive character: Produces an antibiotic substance (proactinomycin) upon synthetic and organic media which is primarily active against various Gram-positive bacteria.

Source: Isolated as an air contaminant at Oxford, England.

* **Appendix I**: The following species probably belong to this genus. Many are incompletely described. Some of the species listed here may belong in the genus *Streptomyces*.

Actinomyces albus acidus Neukirch. (Neukirch, Inaug. Diss., Strassburg, 1902, 50; *Actinomyces albus* var. *acidus* Nannizzi, in Pollacci, Tratt. Micopat. Umana, *4*, 1934, 9.) From a case of keratitis.

Actinomyces avadi Dodge. (*Streptothrix madurae* Koch and Stutzger, Ztschr. f. Hyg., *69*, 1911, 17; not *Streptothrix madurae* Vincent, Ann. Inst. Past., *8*, 1894, 129; Dodge, Medical Mycology, St. Louis, 1935, 729.) From a Madura foot in Egypt, case of Dr. Avad.

Actinomyces bolognesii-chiurcoi (Vuillemin) Dodge. (*Malbrachea bolognesii-chiurcoi* Vuillemin, in Bolognesi and Chiurco, Archivi di Biol., *1*, 1925; Dodge, Medical Mycology, St. Louis, 1935, 766.) From ulcers on the thorax.

Actinomyces cameli (Mason) Sartory and Bailly. (*Streptothrix cameli* Mason, Jour. Trop. Med. and Therap., *32*, 1919, 34; *Oospora cameli* Sartory, Champ. Paras. Homme et Anim., 1923, 822; Sartory and Bailly, Mycoses Pulmonaires, 1923, 253.) From pseudotuberculosis lesions in a camel.

Actinomyces canis (Rabe) Gasperini. (*Discomyces pleuriticus* Vachetta, Studi e ricordi clin. Milano, 1882; *Pleuromyces canis familiaris* Rivolta, Giornali d. Anat. Fisiol. e Patol., *16*, 1884, 4; *Cladothrix canis* Rabe, Berlin. tierärztl. Wochnschr., 1888, 65; Gasperini, Ann. Ist. d'Ig. sper. Univ. Roma, *2*, 1892, 222; *Streptothrix canis* and *Actinomyces pleuriticus canis familiaris*, quoted from Gasperini, Cent. f. Bakt., *15*, 1894, 684; *Leptothrix pleuriticus* Piana and Galli-Vallerio, 1896, quoted from Nannizzi, in Pollacci, Tratt. Micopat. Umana, *4*, 1934, 37; *Nocardia canis* Chalmers and Christopherson, Ann. Trop. Med. and Parasit., *10*, 1916, 255; *Oospora canis* Sartory, Champ. Paras. Homme et Anim., 1923, 821.) Rabe isolated this organism in two cases of phlegmon and a case of peritonitis in dogs.

Actinomyces citrocremeus Nannizzi. (*Mycobacterium diphtheriae avium* Trincas, 1907, quoted from Nannizzi, in Pollacci, Tratt. Micopat. Umana, *4*, 1934, 50; Nannizzi, *idem*.) From a disease in birds.

Actinomyces dassonvillei Brocq-Rousseu. (Brocq-Rousseu, Thèse Sci.

* The appendix was originally prepared by Prof. S. A. Waksman and Prof. A. T. Henrici, May, 1943; it has been developed further by Mrs. Eleanore Heist Clise, Geneva, New York, August, 1945.

Nat. Paris, 1907; *Nocardia dassonvillei* Liégard and Landrieu, Ann. d'Occulistique, *46*, 1911, 418; *Discomyces dassonvillei* Brumpt, Précis de Parasitologie, Paris, 2nd ed., 1913, 976.) Reported from a cervical abscess (Brumpt), from a case of conjunctivitis (Liégard and Landrieu), and from grain (Pinoy, Bull. Inst. Past., *11*, 1913, 923).

Actinomyces dermatonomus Oxer. (Bull. Austral. Jour. Exp. Biol. Med. Sci., *6*, 1929, 301, quoted from Dodge, Medical Mycology, St. Louis, 1935, 719; Oxer, 1930, quoted from Nannizzi, in Pollacci, Tratt. Micopat. Umana, *4*, 1934, 51.) From lesions on sheep in Australia.

Actinomyces donnae Dodge. (*Streptothrix sp.* Donna, Ann. Ig. Sperim., *14*, 1904, 449; Dodge, Medical Mycology, St. Louis, 1935, 745.) From sputum in a pulmonary infection.

Actinomyces dori (Beurmann and Gougerot) Brumpt. (*Sporotrichum*, Dor, Presse Méd., *14*, 1906, 234; *Sporotrichum dori* Beurmann and Gougerot, Ann. Derm. Syphiligr. IV, *7*, 1906, 996; *Discomyces dori* Beurmann and Gougerot, Les Nouvelles Mycoses, 1909, 59; *Rhinocladium dori* Neveu-Lemaire, Précis Parasitol., 1921, 84; *Oospora dori* Sartory, Champ. Paras. Homme et Anim., 1923, 770; Brumpt, Précis de Parasitol., 4th ed., 1927, 1206; *Nocardia dori* Vuillemin, Encyclopédie Mycologique, Paris, *2*, 1931, 284.) Found in subcutaneous abscesses resembling sporotrichosis.

Actinomyces hominis Berestneff. (Berestneff, Inaug. Diss., Moskow, 1897; not *Actinomyces hominis* Waksman, Soil Science, *8*, 1919, 129; *Nocardia hominis* Chalmers and Christopherson, Ann. Trop. Med. and Parasit., *10*, 1916; *Discomyces hominis* Brumpt, Précis de Parasitol., Paris, 3rd ed., 1922, 984.) From a case of pseudoactinomycosis.

Actinomyces japonicus Caminiti. (*Streptothrix sp.* Aoyama and Miyamoto, Mitteil. Med. Fak. K. Jap. Univ. Tokio, *4*, 1901, 231; abst. in Cent. f. Bakt., I Abt., Orig., *29*, 1901, 262; Caminiti, Cent. f. Bakt., I Abt., Orig., *44*, 1907, 198; *Streptothrix japonica* Petruschky, in Kolle and Wasserman, Handb. d. path. Mikroorg., 2 Aufl., *5*, 1913, 295; *Discomyces japonicus* Brumpt, Précis de Parasitol., Paris, 3rd ed., 1922, 981.) From a case of actinomycosis of the lungs.

Actinomyces keratolytica Acton and McGuire. (Indian Med. Gaz., *65*, 1930, 61 and *66*, 1931, 65; *Proactinomyces keratolyticus*, author unknown.) Produces cracked heels among the ryots of India.

Actinomyces lepromatis de Souza-Araujo. (Compt. rend. Soc. Biol., *100*, 1929, 937.) From a leproma, Brazil.

Actinomyces levyi Dodge. (*Actinomyces sp.* Levy; *Oospora sp.* Sartory, Champ. Paras. Homme et Anim., 1923, 827; Dodge, Medical Mycology, St. Louis, 1935, 730.) From pus.

Actinomyces micetomae Greco. (*Streptothrix micetomae argentinae β*, Greco, in Durante, Segunda Observación de Pié de Madura o Micetoma en la República Argentina, Thesis, Buenos Aires, 1911; Greco, Origine des Tumeurs, 1916, 759; *Oospora micetomae* Sartory, Champ. Paras. Homme et Anim., 1923, 783.) From a case of mycetoma pedis.

Actinomyces minimus (LeCalve and Malherbe) Dodge. (*Oospora* forme de *Microsporum* (*Audouini* var. *equinum*), Bodin, Arch. de Parasitol., *2*, 1899, 606; *Trichophyton minimum* LeCalve and Malherbe, Arch. de Parasitol.; *Microsporum minimum* Castellani and Chalmers, Man. Trop. Med., 3rd ed., 1919, 993; Dodge, Medical Mycology, St. Louis, 1935, 728.) From ringworm of horse and dog.

Actinomyces mucosus Basu. (Indian Med. Gaz., *78*, 1943, 577.) From bronchial actinomycosis.

Actinomyces neddeni Namyslowski. (*Streptothrix sp.* zur Nedden, Klin. Monatsbl. f. Augenheilk., *45*, 1907, 152; Namyslowski, Cent. f. Bakt., I

Abt., Orig., *62*, 1912, 564.) From a case of keratitis.

Actinomyces nodosus (Beveridge) Hagan. (*Fusiformis nodosus* Beveridge, Austral. Council Sci. and Indus. Res. Bul. 140, 1941, 56 pp.; Hagan, The Infectious Diseases of Domestic Animals. Ithaca, New York, 1943, 312.) Considered the primary cause of foot-rot of sheep. Also see *Spirochaeta penortha*.

Actinomyces phenotolerans Werkman. (In Gammel, Arch. Derm. Syphilol., *29*, 1934, 286.) From granuloma in man.

Actinomyces puntonii López Ortega. (López Ortega, Annali d'Igiene, Rome, *44*, 1934, 867; *Asteroides puntonii* Puntoni and Leonardi, Boll. e Atti d. R. Accad. Med. di Roma, *61*, 1935, 94.) From a pulmonary abscess.

Actinomyces purpureus Cavara. (Orloff, Vestnik Ofth., *29*, 1912, 653; Cavara, Micosi Occ., 1928, 99; not *Actinomyces purpureus* Killian and Fehér, Ann. Inst. Past., *55*, 1935, 620.) From a case of keratitis in Russia.

Actinomyces ribeyro Dodge. (*Hongo artrosporado* Ribeyro, Ann. Fac. Med. Lima, *3*, 1919, 1; Dodge, Medical Mycology, St. Louis, 1935, 735.) From a generalized infection on the arms, legs and chest of a patient in Peru.

Actinomyces rodellae Dodge. (*Streptothrix sp.* Rodella, Cent. f. Bakt., I Abt., Orig., *84*, 1920, 450; Dodge, Medical Mycology, St. Louis, 1935, 734.) From abscesses of the tooth and jaw.

Actinomyces ruber (Kruse) Sanfelice. (Un *Cladothrix* cromogeno, Ruiz Casabó, Cronica medico-quirurgica de la Habana, *20*, No. 13, 1894, 340; see Cent. f. Bakt., I Abt., *17*, 1895, 466; *Streptothrix rubra* Kruse, in Flügge, Die Mikroorganismen, 3 Aufl., *2*, 1896, 63; *Cladothrix rubra* Macé, Traité Pratique de Bact., 4th ed., 1901, 1097; not *Actinomyces ruber* Krainsky, Cent. f. Bakt., II Abt., *41*, 1914, 662; Sanfelice, Cent. f. Bakt., I Abt., Orig., *36*, 1904, 355; *Nocardia rubra* Chalmers and Christopherson, Ann. Trop. Med. and Parasit., *10*, 1916, 265; *Discomyces ruber* Brumpt, Précis de Parasitol., Paris, 3rd ed., 1922, 981.) From sputum. Some authors consider the following synonymous with this organism: *Streptothrix mineacea* (*Actinomyces mineaceus* Lachner-Sandoval, Ueber Strahlenpilze, 1898, 66).

Actinomyces rubidaureus Lachner-Sandoval. (*Cladothrix* mordoré, Thiry, Arch. Physiol. Norm. et Path., *9*, 1897, 283; Lachner-Sandoval, Ueber Strahlenpilze, Inaug. Diss., Strassburg, 1898, 66; *Actinomyces* mordoré, Thiry, Thèse, Nancy, 1900, 82; *Nocardia* mordoré, Chalmers and Christopherson, Ann. Trop. Med. and Parasit., *10*, 1916, 265; *Nocardia thiryei* de Mello and Pais, Arq. Hig. Pat. Exot., *6*, 1918, 193; *Discomyces thiryi* Brumpt, Précis de Parasitol., Paris, 3rd ed., 1922, 981; *Oospora* mordoré, Sartory, Champ. Paras. Homme et Anim., 1923, 824; *Actinomyces thiryi* Sartory and Bailly, Mycoses Pulmonaires, 1923, 252.) From a case showing anginous exudate with edema.

Actinomyces salvati Langeron. (Langeron, Bull. Soc. Path. Exot., *15*, 1922, 526; Fontoynont and Salvat, *ibid.*, 596.) From generalized nodular lesions in the Madagascar rat.

Actinomyces sartoryi Dodge. (*Oospora pulmonalis* var. acido-resistant, Sartory, Arch. Med. Pharm. Milit., *70*, 1916, 605; Dodge, Medical Mycology, St. Louis, 1935, 756.) From a patient showing symptoms of pulmonary tuberculosis.

Actinomyces septicus MacNeal and Blevins. (Jour. Bact., *49*, 1945, 605.) From human endocarditis.

Actinomyces serratus Dodge. (*Actinomyces asteroides* var. *serratus* Sartory, Meyer and Meyer, Ann. Inst. Past., *44*, 1930, 298; also see Compt. rend. Acad. Sci. Paris, *188*, 1929, 745; Dodge, Medical Mycology, St. Louis, 1935, 745.) From a case of actinomycosis of bones with yellow grains.

Actinomyces sommeri Greco. (*Streptothrix madurae* Greco, Primer Caso de

Pié de Madura o Micetoma en la República Argentina, Thesis, Buenos Aires, 1904; *Streptothrix micetomas argentinae* α, Greco, in Durante, Segunda Observación de Pié de Madura o Micetomá en la República Argentina, Thesis, Buenos Aires, 1911; Greco, Origine des Tumeurs, 1916, 726; *Nocardia micetomae-argentinae* Durant, 1911, quoted from Brumpt, Précis de Parasitol., Paris, 3rd ed., 1922, 985; *Oospora sommeri* Sartory, Champ. Paras. Homme et Anim., 1923, 783.) From a case of mycetoma pedis in Argentina.

Actinomyces tossicus Dodge. (*Actinomyces albus* var. *tossica* Rossi, Ann. Ig. Sperim., *9*, 1905, 693; *Oospora alba* var. toxique, Sartory, Champ. Paras. Homme et Anim., 1923, 829; Dodge, Medical Mycology, St. Louis, 1935, 719.) From tumors in the abdominal cavities of domestic fowl.

Actinomyces urethridis Brumpt. (Précis de Parasitol., Paris, 4th ed., 1927, 1206.) Isolated by Roček in 1920 from cases of prostatitis.

Actinomyces variabilis Cohn. (Cent. f. Bakt., I Abt., Orig., *70*, 1913, 301.) From pus in the bladder in a case of cystitis and from the prostate.

Asteroides pseudocarneus Puntoni and Leonardi. (Boll. e Atti d. R. Accad. Med. di Roma, *61*, 1935, 93.)

Bacillus berestnewi Lepeschkin. (Cent. f. Bakt., II Abt., *12*, 1904, 641 and *13*, 1904, 13.) From sputum of a pneumonia patient.

Bacillus (*Micrococcus?*) *havaniensis* Sternberg. (Sternberg, Manual of Bact., 1893, 718; *Bacterium havaniensis* Chester, Ann. Rept. Del. Col. Agr. Exp. Sta., *9*, 1897, 116; *Serratia havaniensis* Bergey et al., Manual, 1st ed., 1923, 95.) From human intestinal canal.

Cladothrix matruchoti Mendel. (Mendel, Compt. rend. Soc. Biol., *82*, 1919, 583; *Nocardia matruchoti* Pettit, 1921, quoted from Nannizzi, in Pollacci, Tratt. Micopat. Umana, *4*, 1934, 51; *Oospora matruchoti*, quoted from Nannizzi, *idem*; *Actinomyces matruchoti* Nannizzi, *idem*.) From the roots of a decaying tooth with tumefaction. Species dubia.

Cohnistrepothrix misri Carpano. (Riv. di Parassitologia, n. 2, p. 107; quoted from Boll. d. Sez. Ital. d. Soc. Internat. d. Microbiol., *10*, 1938, 62.) From human dermatosis in Egypt.

Discomyces berardinisi Brumpt. (*Streptothrix sp.* de Berardinis, Ann. Ottalmol. Lavori Clin. Oculist. Napoli, *33*, 1904, 914; Actinomyces de Berardinis, Namyslowski, Cent. f. Bakt., I Abt., Orig., *62*, 1912, 566; Brumpt, Précis de Parasitol., Paris, 3rd ed., 1922, 977; *Actinomyces bernardinisi* Brumpt, *ibid.*, 4th ed., 1927, 1189; *Nocardia berardinisi* Vuillemin, Encyclopédie Mycologique, Paris, *2*, 1931, 126.) From a case of keratitis.

Discomyces brasiliensis Lindenberg. (Lindenberg, Rev. med. de S. Paolo, 1909, No. 18, and Arch. de Parasitol., *13*, 1909, 265; *Nocardia brasiliensis* Pinoy, Bull. Inst. Past., Paris, *11*, 1913, 936; *Streptothrix brasiliensis* Greco, Origine des Tumeurs, 1916, 724; *Oospora brasiliensis* Sartory, Champ. Paras. Homme et Anim., 1923, 786; *Actinomyces brasiliensis* Gomes, Ann. Palistas Med. Cirurg., *14*, 1923, 150.) From a case of mycetoma of the leg. According to Pinoy and others, idential with *Nocardia asteroides*.

Discomyces congolensis Baerts. (Baerts, Bull. Méd. Katanga, *2*, 1925, 67; *Actinomyces congolensis* Brumpt, Précis de Parasitol., Paris, 4th ed., 1927, 1206.) From lesions in a case of actinomycosis from the Belgian Congo.

Discomyces dispar (Vidal) Brumpt. (*Microsporon dispar* Vidal, 1882, *Microsporon anemoeon* Vidal, 1882 and *Sporotrichum dispar*, quoted from Brumpt, Précis de Parasitol., Paris, 3rd ed., 1922, 995 and from Nannizzi, in Pollacci, Tratt. Micopat. Umana, *4*, 1934, 25; Brumpt, *idem*; *Actinomyces dispar* Brumpt, *ibid.*, 4th ed., 1927, 1206.)

From a case of pityriasis. Species dubia.

Discomyces mexicanus Boyd and Crutchfield. (Boyd and Crutchfield, Amer. Jour. Trop. Med., *1*, 1921, 268; *Actinomyces mexicanus* Brumpt, Précis de Parasitol., Paris, 4th ed., 1927, 1192; *Nocardia mexicana* Ota, Jap. Jour. Derm. Urol., *28*, 1928.) From a mycetoma of the foot.

Discomyces minutissimus (Burchardt) Brumpt. (*Microsporon minutissimum* Burchardt, in Uhle and Wagn. Pat. Gen., 1859; *Trichothecium sp.* J. Neumann, 1868; *Microsporon gracile* Balzer, Ann. Derm. Syphiligr., II, *4*, 1883, 681; *Sporotrichum minutissimum* Saccardo, Sylloge Fungorum, *4*, 1886, 100; *Microsporoides minutissimus* Neveu-Lemaire, Précis Parasitol., 1906; Brumpt, Précis de Parasitol., 1st ed., 1910, 863; *Oospora minutissima* Ridet, Oospora et Oosporoses, 1911, 68; *Nocardia minutissima* Verdun, Précis parasitol., 1912; *Actinomyces minutissimus* Brumpt, *ibid.*, 4th ed., 1927, 1199.) Reported as the etiological agent of erythrasma.

Mycobacterium alluvialum Bergey et al. (Kersten, Cent. f. Bakt., I Abt., Orig., *51*, 1909, 494; Bergey et al., Manual, 1st ed., 1923, 379.) From soil.

Mycobacterium convolutum Gray and Thornton. (Gray and Thornton, Cent. f. Bakt., II Abt., *73*, 1928, 87; *Actinomyces convolutus* Bergey et al., Manual, 3rd ed., 1930, 473.) From soil. Resembles *Nocardia opaca*.

Nocardia arborescens (Edington) Trevisan. (*Bacillus arborescens* Edington, Brit. Med. Jour., June 11, 1887, 1262; Trevisan, I generi e le specie delle Batteriacee, 1889, 9; *Actinomyces arborescens* Gasperini, Cent. f. Bakt., *15*, 1894, 684.) From human skin in cases of scarlatina.

Nocardia bahiensis da Silva. (Da Silva, Brasil Med., *33*, 1919, 81 and Mem. Inst. Butantan, *1*, 1918–1919, 187; *Discomyces bahiensis* Neveu-Lemaire, Précis de Parasitol. Hum., 5th ed., 1921, 44; *Oospora bahiensis* Sartory, Champ. Paras. Homme et Anim., 1923, 784; *Actinomyces bahiensis* Brumpt, Précis de Parasitol., 4th ed., 1927, 1195.) From an actinomycotic mycetoma in Brazil.

Nocardia berestneffi Chalmers and Christopherson. (Streptothrix cas I, II, Berestneff, Inaug. Diss., Moscow, 1897; Chalmers and Christopherson, Ann. Trop. Med. and Parasitol., *10*, 1916, 263; *Discomyces berestneffi* Brumpt, Précis de Parasitol., Paris, 3rd ed., 1922, 992; *Actinomyces berestneffi* Sartory and Bailly, Mycoses pulmonaires, 1923, 256.) From a case of pulmonary pseudotuberculosis.

Nocardia bicolor (Trolldenier) de Mello and Fernandes. (*Actinomyces bicolor* Trolldenier, Ztschr. f. Tiermedizin, *7*, 1903, 81; de Mello and Fernandes, Mem. Asiatic Soc. Bengal, *7*, 1919, 106.) Found in cerebromeningitis, bronchitis and lymphadenitis in a dog.

Nocardia convoluta Chalmers and Christopherson. (Chalmers and Christopherson, Ann. Trop. Med. and Parasit., *10*, 1916, 257; *Discomyces convolutus* Neveu-Lemaire, Précis Parasitol. Hum., 5th ed., 1921, 44; *Oospora convoluta* Sartory, Champ. Paras. Homme et Anim., 1923, 769; *Actinomyces convolutus* Brumpt, Précis de Parasitol., Paris, 4th ed., 1927, 1195.) From a yellow grain mycetoma of the foot in the Sudan.

Nocardia cylindracea de Korté. (De Korté, Ann. Trop. Med. Parasit., *11*, 1918, 205; *Discomyces cylindraceus* Neveu-Lemaire, Précis Parasitol. Hum., 5th ed., 1921, 44; *Oospora cylindracea* Sartory, Champ. Paras. Homme et Anim., 1923, 774; *Actinomyces cylindraceus* Brumpt, Précis de Parasitologie, Paris, 4th ed., 1927, 1206.) From an infection of the outer ear, resembling mycetoma.

Nocardia enteritidis (Pottien) Castellani and Chalmers. (*Streptothrix enteritidis* Pottien, 1902, according to Sanfelice, Cent. f. Bakt., I Abt., Orig., *36*,

1904, 357; *Bacillus enteritidis* Pottien, 1902, according to Nannizzi, in Pollacci, Tratt. Micopat. Umana, *4*, 1934, 25; not *Bacillus enteritidis* Gaertner, Correspond. d. Allgemein. Artz. Vereins Thuringen, *17*, 1888, 573; Castellani and Chalmers, Man. Trop. Med., 2nd ed., 1913, 819; *Oospora enteritidis*, quoted from Nannizzi, *loc. cit.*; *Discomyces enteritidis* Brumpt, Précis de Parasitol., Paris, 3rd ed., 1922, 980; *Actinomyces enteritidis* Brumpt, *ibid.*, 4th ed., 1927, 1191.) From a case of enteritis.

Nocardia equi Chalmers and Christopherson. (*Streptothrix sp.* Dean, Trans. Path. Soc. London, *51*, 1900, 26; Chalmers and Christopherson, Ann. Trop. Med. Parasit., *10*, 1916, 263; *Discomcyes equi* Brumpt, Précis de Parasitologie, 3rd ed., 1922, 992; *Actinomyces equi* Sartory and Bailly, Mycoses Pulmonaires, 1923, 256.) From an abscess on the jaw of a horse.

Nocardia erythrea (Foulerton) Chalmers and Christopherson. (*Streptothrix erythrea* Foulerton, 1910; Chalmers and Christopherson, Ann. Trop. Med. and Parasit., *10*, 1916, 268.)

Nocardia foulertoni Chalmers and Christopherson. (*Streptothrix hominis* Foulerton and Jones, Trans. Path. Soc. London, *53*, 1902, 56; *Streptothrix hominis I* Foulerton, in Allbutt and Rolleston, Syst. of Medicine, *2*, 1906, 302; *Nocardia hominis* Castellani and Chalmers, Man. Trop. Med., 2nd ed., 1913, 819; *Oospora hominis* Ridet, 1911, according to Castellani and Chalmers, *idem*; Chalmers and Christopherson, Ann. Trop. Med. and Parasit., *10*, 1916, 263; *Discomyces foulertoni* Brumpt, Précis de Parasitol., Paris, 3rd ed., 1922, 993; *Actinomyces foulertoni* Brumpt, *ibid.*, 4th ed., 1927, 1204.) From abscesses of the chest and from sputum.

Nocardia genesii Fróes. (Fróes, Do mycetoma pedis no Brasil 50, 1930; *Actinomyces genesii* Dodge, Medical Mycology, St. Louis, 1935, 761.) From a case of Genesio Salles from Bahia.

Nocardia jollyi Vuillemin. (Vuillemin, in Jolly, Rev. Med. de l'Est, *48* 1920, 42; *Discomyces jollyi* Brumpt, Précis de Parasitol., Paris, 3rd ed., 1922, 84; *Oospora jollyi* Sartory, Champ. Paras. Homme et Anim., 1923, 770; *Actinomyces jollyi* Brumpt, *ibid.*, 4th ed., 1927, 1196.) From a case clinically resembling bubonic plague.

Nocardia lasserei Verdun. (*Nocardia sp.* Lasserre, Thèse Toulouse, 1904; Verdun, Précis Parasitol., 1912; *Discomyces lasserrei* Neveu-Lemaire, Précis Parasitol. Hum., 5th ed., 1921, 43; *Oospora lasserei* Sartory, Champ. Paras. Homme et Anim., 1923, 798, *Actinomyces lasserei* Brumpt, Précis de Parasitol., 4th ed., 1927, 1206.) From an ulcerative lesion on the pharynx and upper lip.

Nocardia lingualis (Eisenberg) Chalmers and Christopherson. (Zungenbelag-Vibrio, Weibel, Cent. f. Bakt., *4*, 1888, 227; *Vibrio lingualis* Eisenberg, Bakt. Diag., 3 Aufl., 1891, 212; *Spirillum linguae* Sternberg, Man. of Bact., 1893, 697; *Spirosoma lingualis* Migula, in Engler and Prantl, Die natürl. Pflanzenfam., *1*, la, 1895, 31; *Streptothrix lingualis* Bajardi, Cent. f. Bakt., I Abt., Orig., *35*, 1904, 129; Chalmers and Christopherson, Ann. Trop. Med. and Parasit., *10*, 1916, 265; not *Nocardia lingualis* Castellani and Chalmers, Man. Trop. Med., 2nd ed., 1913, 819; *Discomyces lingualis* Brumpt, Précis de Parasitol., Paris, 3rd ed., 1922, 980; *Actinomyces lingualis* Sartory and Bailly, Mycoses Pulmonaires, 1923, 252.) From a deposit on the tongue. Jensen (Proc. Linn. Soc. New So. Wales, *59*, 1934, 43) regards this species as closely related to *Corynebacterium filamentosum*. Also see page 205.

Nocardia londinensis (sic) Chalmers and Christopherson. (*Streptothrix hominis II*, Foulerton, Lancet, *1*, 1906, 970; Chalmers and Christopherson, Ann. Trop. Med. and Parasit., *10*, 1916, 256; *Discomyces londinensis* Brumpt, Précis de Parasitol., Paris, 3rd ed., 1922, 993; *Actinomyces londinensis* Brumpt, *ibid.*,

4th ed., 1927, 1204.) From cases of human actinomycosis.

Nocardia macrodipodidarum Fox. (Fox, Disease in Captive Wild Mammals and Birds, 1923, 570; *Actinomyces macrodipodidarum* Dodge, Medical Mycology, St. Louis, 1935, 747.) Found in lumpy jaw with septicemia and gasteroenteritis of kangaroos.

Nocardia nicollei Delanoë. (Delanoë, Arch. Inst. Past. Tunis, *17*, 1928, 257; *Actinomyces nicollei* Nannizzi, in Pollacci, Tratt. Micopat. Umana, *4*, 1934, 36.) From a mycetoma of the thigh.

Nocardia nigra (Castellani) Castellani and Chalmers. (*Streptothrix nigra* Castellani, 1913, according to Castellani and Chalmers, Man. Trop. Med., 3rd ed., 1919, 1062; presumably not *Streptothrix nigra* Rossi Doria, Ann. Ist. Ig. sper. Univ. Roma, *1*, 1891, 399; Castellani and Chalmers, *idem.*) From black granules in a case of tonsillar nocardiomycosis. Usually forms black colonies on agar.

Nocardia panginensis de Mello and Fernandes. (De Mello and Fernandes, Mem. Asiatic Soc. Bengal, *7*, 1919, 130; *Actinomyces panginensis* Dodge, Medical Mycology, St. Louis, 1935, 718.) From a dermatosis.

Nocardia pijperi Castellani and Chalmers. (*Nocardia sp.* Pijper, Folia Microbiol., *5*, 1917, 50 and Med. Jour. So. Africa, *12*, 1917, 141; Castellani and Chalmers, Man. Trop. Med., 3rd ed., 1919, 1060; *Discomyces pijperi* Neveu-Lemaire, Précis Parasitol. Hum., 5th ed., 1921, 44; *Actinomyces pijperi* Sartory and Bailly, Mycoses pulmonaires, 1923, 256.) From sputum in a case of chronic bronchitis.

Nocardia pinoyi de Mello and Fernandes. (De Mello and Fernandes, Mem. Asiatic Soc. Bengal, *7*, 1919, 130; *Actinomyces pinoyi* Dodge, Medical Mycology, St. Louis, 1935, 723.) From a case of erythrasma.

Nocardia ponceti Verdun. (Verdun, Précis Parasitol., 1912; *Discomyces ponceti* Neveu-Lemaire, Précis Parasitol. Hum., 5th ed., 1921, 43; *Oospora ponceti* Sartory, Champ. Paras. Homme et Anim., 1923, 778; *Actinomyces ponceti* Brumpt, Précis de Parasit., Paris, 4th ed., 1927, 1205.) Isolated by Moorhof, Dor and Poncet from a muscular pseudo-actinomycosis. This species may be synonymous with *Nocardia krausei* (Chester).

Nocardia putridogenes (Vezspremi) de Mello and Pais. (*Cladothrix putridogenes* Vezspremi, Cent. f. Bakt., I Abt., *44*, 1907, 408 and 515; de Mello and Pais, Arq. Hig. Pat. Exot., *6*, 1918, 187; *Oospora putridogenes* Sartory, Champ. Paras. Homme et Anim., 1923, 823; *Actinomyces putridogenes* Nannizzi, in Pollacci, Tratt. Micopat. Umana, *4*, 1934, 41.) From greenish pus from gingival ulcers and abscess of the jaw.

Nocardia repens (Eklund) Vuillemin. (*Epidermophyton sp.* Lang, 1879; *Lepocolla repens* Eklund, 1883; *Achorion repens* Guéguen, 1904; *Epidermophyton repens*; all quoted from Nannizzi, in Pollacci, Tratt. Micopat. Umana, *4*, 1934; Vuillemin, Encyclopédie Mycologique, Paris, *2*, 1931, 124; *Actinomyces repens* Nannizzi, *idem.*) From the skin in cases of psoriasis.

Nocardia rivierei Verdun. (*Streptothrix sp.* Rivière, Cong. Franç. Méd. Bordeaux 1895, *2*, 1896, 1003; *Actinomyces* Sabrazes et Rivieri, Berestnev, Inaug. Diss., Moscow, 1897; Verdun, Précis Parasitol., 1912; *Discomyces rivierei* Neveu-Lemaire, Précis Parasitol. Hum., 5th ed., 1921, 43; *Oospora rivierei* Sartory, Champ. Paras. Homme et Anim., 1923, 792; *Actinomyces rivierei* Brumpt, Précis de Parasitol., 4th ed., 1927, 1201.) From sputum and pus in a bronchopleuropulmonary infection followed by multiple abscesses.

Nocardia sanfelicei Redaelli. (Streptothrix acido-resistente, Sanfelice, Boll. Ist. Sieroterapico Milanese, *2*, 1922, 327; Redaelli, Ist. Sieroterapico Milanese, *7*, 1928, 75 and 121; *Actinomyces*

sanfelicei Nannizzi, in Pollacci, Tratt. Micopat. Umana, *4*, 1934, 51.) From fatal lesions in a rat.

Nocardia splenica Gibson. (Gibson, 1930, quoted from Nannizzi, in Pollacci, Tratt. Micopat. Umana, *4*, 1934, 50; *Actinomyces splenica* Nannizzi, *idem.*) From a case of splenomegalia.

Nocardia tenuis Castellani. (Castellani, Brit. Jour. Derm. Syphilis, *23*, 1911, 341; *Discomyces tenuis* Castellani, Proc. Roy. Soc. Med., *6*, Derm., 1912, 23; *Cohnistreptothrix tenuis* Chalmers and Christopherson, Ann. Trop. Med. and Parasit., *10*, 1916, 273; *Actinomyces tenuis* Dodge, Medical Mycology, St. Louis, 1935, 715.) From cases of trichomycosis flava.

Nocardia valvulae Chalmers and Christopherson. (*Streptothrix valvulae destruens bovis* Luginger, Monats. f. prakt. Tierheilk., *15*, 1904, 289; Chalmers and Christopherson, Ann. Trop. Med. and Parasit., *10*, 1916, 263; *Oospora valvulae destruens bovis* Sartory, Champ. Paras. Homme et Anim., 1923, 788; *Actinomyces valvularis* Ford, Textb. of Bact., 1927, 211; *Actinomyces valvulae* Nannizzi, in Pollacci, Tratt. Micopat. Umana, *4*, 1934, 51.) From endocarditis in cattle.

Oospora anaerobies Sartory. (*Actinomyces sp.* Butterfield, Jour. Inf. Dis., *2*, 1905, 421; Sartory, Champ. Parasit. Homme et Anim., 1923, 830; *Actinomyces anaerobies* Plaut, quoted from Dodge, Medical Mycology, St. Louis, 1935, 717.) From pus from human lung.

Oospora bronchialis Sartory and Levasseur. (Sartory and Levasseur, 1914, quoted from Neveu-Lemaire, Précis Parasitol. Hum., 5th ed., 1921, 43; *Actinomyces bronchialis* Sartory, Bull. Sci. Pharm., *23*, 1916, 12; *Discomyces bronchialis* Neveu-Lemaire, *idem.*) From sputum in a case of pulmonary oosporosis.

Oospora buccalis Roger, Bory and Sartory. (Roger, Bory and Sartory, Bull. Mem. Soc. Méd. Hôp. Paris, *27*, 1909, 319 and Compt. rend. Soc. Biol., *66*, 1909, 301; *Discomyces buccalis* Brumpt, Précis de Parasitol., Paris, 1st ed., 1910, 861; *Nocardia buccalis* Castellani and Chalmers, Man. Trop. Med., 2nd ed., 1913, 819; *Actinomyces buccalis* Sartory and Bailly, Mycoses pulmonaires, 1923, 256.) From a case of creamy stomatitis with tonsillar abscess.

Oospora catarrhalis Sartory and Bailly. (Sartory and Bailly, Thèse Univ. Strasbourg Fac. Pharm., *4*, 1921, 57; *Discomyces catarrhalis* Brumpt, Précis de Parasitol., Paris, 3rd ed., 1922, 984; *Actinomyces catarrhalis* Brumpt, *ibid.*, 4th ed., 1927, 1195.) From sputum in a case of pulmonary oosporosis.

Oospora hominis Ridet. (*Streptothrix hominis IV* Foulerton, 1906; *Streptothrix hominis III* Foulerton, 1910; Ridet, 1911, according to Nannizzi, in Pollacci, Tratt. Micopat. Umana, *4*, 1934, 9; *Nocardia appendicis* Chalmers and Christopherson, Ann. Trop. Med. and Parasit., *10*, 1916, 256; *Discomyces appendicis* Brumpt, Précis de Parasitol., 3rd ed., 1922, 977; *Actinomyces appendicis* Brumpt, *ibid.*, 4th ed., 1927, 1189.) From a case of appendicitis and an iliac abscess.

Oospora lingualis Guéguen. (Guéguen, Compt. rend. Soc. Biol., *64*, 1908, 852; *Discomyces lingualis* Brumpt, Précis de Parasitol., Paris, 1st ed., 1910, 865 and 2nd ed., 1913, 976; not *Discomyces lingualis* Brumpt, *ibid.*, 3rd ed., 1922, 980; *Nocardia lingualis* Castellani and Chalmers, Man. Trop. Med., 2nd ed., 1913, 819; not *Nocardia lingualis* Chalmers and Christopherson, Ann. Trop. Med. and Parasitol., *10*, 1916, 265; *Discomyces gueguení* Brumpt, *ibid.*, 3rd ed., 1922, 980; *Actinomyces gueguení* Brumpt, *ibid.*, 4th ed., 1927, 1191; *Nocardia gueguení* Ota, Jap. Jour. Derm Urol., *28*, 1928.) From cases of lingua nigra.

Oospora pulmonalis Roger, Sartory and Bory. (Roger, Sartory and Bory, Compt. rend. Soc. Biol., *66*, 1909, 150; *Discomyces pulmonalis* Brumpt, Précis

de Parasitologie, 1st ed., 1910, 860; *Nocardia pulmonalis* Castellani and Chalmers, Man. Trop. Med., 2nd ed., 1913, 817; *Actinomyces pulmonalis* Sartory and Bailly, Mycoses Pulmonaires, 1923, 256.) From the sputum of a patient with pulmonary mycosis.

Oospora pulmonalis var. *chromogena* Sartory. (Sartory, 1913; *Actinomyces pulmonalis* var. *chromogenus* Nannizzi, in Pollacci, Tratt. Micopat. Umana, *4*, 1934, 39.) From sputum of a patient suspected of having pulmonary tuberculosis.

Proactinomyces albus Krassilnikov. (Bull. Acad. Sci., U. S. S. R., No. 1, 1938, 139.) Cells at first produce mycelium with frequent branching varying in diameter from 0.6 to 1.0 micron. Breaks up after 2 or 3 days into rods and sometimes later into cocci. Multiply by fission, cross-wall formation and budding. Does not form spores; cells are Gram-positive and are not acid-fast. Colorless growth. Colonies vary in the different strains, somewhat rough, folded, shiny or dull, of a dough-like consistency. Krassilnikov listed several strains of this organism, including *Proactinomyces oligocarbophilus*.

Proactinomyces aquosus Turfitt. (Jour. Bact., *47*, 1944, 490.) From soil. Decomposes cholesterol.

Proactinomyces cyaneus (Beijerinck) Krassilnikov. (*Actinococcus cyaneus* Beijerinck, Folia microbiol., Delft, *2*, 1914, 196; Krassilnikov, *loc. cit.*) Blue pigment produced on synthetic media. Cells are rod-shaped. 0.7 to 0.8 by 3 to 7 microns. Branching cell material on potato multiplies by means of bud formation, by fission, and cross-wall formation; no true spores formed.

Proactinomyces cyaneus-antibioticus Gause. (Jour. Bact., *51*, 1946, 649.) From soil. Produces litmocidin, a new antibiotic.

Proactinomyces moormani Franklin. (Ann. Intern. Med., *13*, 1940, 1205.) From the pus of multiple molar abscesses in a dental patient.

Proactinomyces paraguayensis Almeida. (Mycopath., *2*, 1940, 201.) From a thoracic mycetoma with heavy, dark grains affecting a Canadian patient living in the Paraguayan Chaco. Sabouraud's glucose agar: Pseudomembranous colony with raised, dark center surrounded by a white band, progressively increasing in size, and then by a light chocolate area.

Proactinomyces restrictus Turfitt. (Jour. Bact., *47*, 1944, 491.) From soil. Decomposes cholesterol.

Proactinomyces sp. Helzer. Found in sputum of tuberculous patient. Pathogenic for guinea pigs and rabbits.

Streptothrix buccalis Goadby. (Mycology of the Mouth, London, 1903, 200.) From the mouth in cases of pyorrhoea. Chalmers and Christopherson (Ann. Trop. Med. and Parasit., *10*, 1916, 234) regard this as a synonym of *Nocardia liquefaciens*.

Streptothrix flava Chester. (*Actinomyces sp.* Bruns, Cent. f. Bakt., *26*, 1899, 11; Chester, Man. Determ. Bact., 1901, 362; *Nocardia bruni* Chalmers and Christopherson, Ann. Trop. Med. and Parasit., *10*, 1916, 256; *Streptothrix hominis* Bruns, according to Chalmers and Christopherson, *idem*; *Discomyces bruni* Brumpt, Précis de Parasitol., Paris, 3rd ed., 1922, 992; *Actinomyces bruni* Brumpt, *ibid.*, 4th ed., 1927, 1204; *Actinomyces flavus* Dodge, Medical Mycology, St. Louis, 1935, 752.) From pus from a case of actinomycosis of the abdominal wall.

Streptothrix fusca Karwacki. (Karwacki, Compt. rend. Soc. Biol., *66*, 1911, 180; not *Streptothrix fusca* Corda, Prachtflora europäischer Schimmelbildungen, Leipzig and Dresden, 1839, 27; *Nocardia fusca* Castellani and Chalmers, Man. Trop. Med., 2nd ed., 1913, 818; *Discomyces fuscus* Brumpt, Précis de Parasitol., Paris, 3rd ed., 1922, 993; *Oospora fusca* Sartory, Champ. Paras.

Homme et Anim., 1923, 809; *Actinomyces fuscus* Sartory and Bailly, Mycoses pulmonaires, 1923, 256; not *Actinomyces fusca* Söhngen and Fol, Cent. f. Bakt., II Abt., *40*, 1914, 87.) From the sputum of a tuberculosis patient.

Streptothrix luteola Foulerton and Jones. (Foulerton and Jones, Trans. Path. Soc. London, *53*, 1902, 75; also see Foulerton, Lancet, *1*, 1905, 1200 and *1*, 1906, 970; *Nocardia luteola* Castellani and Chalmers, Man. Trop. Med., 2nd ed., 1913, 818; *Discomyces luteolus* Brumpt, Précis de Parasitol., Paris, 3rd ed., 1922, 981; *Oospora luteola* Sartory, Champ. Paras. Homme et Anim., 1923, 812; *Actinomyces luteolus* Ford, Textb. of Bact., 1927, 213.) From a lung infection, from a case of conjunctivitis, and from a dental abscess.

Streptothrix madurae Solari. (Solari, Semana Méd., *24*, 1917, 573; not *Streptothrix madurae* Vincent, Ann. Inst. Past., *8*, 1894, 129; not *Streptothrix madurae* Koch and Stutzger, Ztschr. f. Hyg., *69*, 1911, 17.) From Madura foot. See *Actinomyces avadi*.

Streptothrix muris-ratti Schottmüller. (Schottmüller, Derm. Wochnschr., *58*, 1914, 77; *Nocardia muris* de Mello and Pais, Arq. Hig. Pat. Exot., *6*, 1918, 183; *Actinomyces muris-ratti* Nannizzi, in Pollacci, Tratt. Micopat. Umana, *4*, 1934, 51.) From sodoku or rat-bite fever.

Streptothrix tarozzii Miescher. (*Actinomyces albus* Tarozzi, Archivio Sci. Med., *33*, 1909, 553; Miescher, Arch. Derm. Syphilis, *124*, 1917, 297; *Actinomyces tarozzii* Dodge, Medical Mycology, St. Louis, 1935, 735.) From a case of Madura foot.

Streptothrix verrucosa (Adler) Miescher. (*Actinomyces verrucosus* Adler, 1904, see Nannizzi, in Pollacci, Tratt. Micopat. Umana, *4*, 1934, 46; Miescher, Arch. Derm. Syphilis, *124*, 1917, 314.) From mycetoma pedis.

Genus II. Actinomyces *Harz.*

(Harz, in Bollinger, Centbl. f. med. Wissensch., *15*, 1877, 485; Harz, Jahresber. d. Münch. Thierarzneischule for 1877–78, 1879, 125; not *Actinomyce* Meyen, Linnaea, *2*, 1827, 442; *Discomyces* Rivolta, Clinica Veter., Milano, *1*, 1878, 208; *Actinocladothrix* Afanasiev, St. Petersb. med. Wchnschr., *4*, 1887, 323; *Micromyces* Gruber, Cent. f. Bakt., *10*, 1891, 648; not *Micromyces* Dangeard, Le Botaniste, *1*, 1888, 55; *Actinobacterium* Haas, Cent. f. Bakt., I Abt., Orig., *40*, 1906, 180; *Carteria* and *Carterii* Musgrave, Clegg and Polk, Philippine Jour. Sci., Ser. B, Med. Sci., *3*, 1908, 470; *Cohnistreptothrix* Pinoy (in part), 1911, see Pinoy, Bull. Inst. Past., *11*, 1913, 929; *Anaeromyces* Castellani, Douglas and Thomson, Jour. Trop. Med. Hyg., *24*, 1921, 149; *Brevistreptothrix* Lignières, Ann. Parasit. Hum. Comp., *2*, 1924, 1.)

True mycelium produced. The vegetative mycelium fragments into elements of irregular size and may exhibit angular branching. No conidia produced. Not acid-fast. Anaerobic to microaerophilic. Pathogenic for man and animals.

The type species is *Actinomyces bovis* Harz.

Key to the species of genus Actinomyces.

I. Colonies soft, smooth, uniform, not adherent to medium. No aerial hyphae.
   1. *Actinomyces bovis.*

II. Colonies tougher in texture and warted in appearance, adherent to medium. Scanty aerial growth of hyphae.
   2. *Actinomyces israeli.*

1. **Actinomyces bovis** Harz. (Harz, in Bollinger, Cent. f. med. Wissensch., *15*, 1877, 485; Jahrb. d. Münch. Thierarzeneischule, 1877, 781; *Discomyces bovis* Rivolta, La clinica Veterinaria, *1*, 1878, 169 or 208; *Bacterium actinocladothrix* Afanasiev, St. Petersburger Med. Wochnschr., *13*, 1888, 84; *Nocardia actinomyces* Trevisan, I generi e le specie delle Batteriacee, Milan, 1889, 9; *Streptotrix actinomyces* Rossi Doria, Ann. d. Ist. d'Igi. Sper., Univ. di Roma, *1*, 1891, 425; *Cladothrix bovis* Macé, Traité de Bact., 2nd ed., 1891, 666; *Oospora bovis* Sauvageau and Radais, Ann. Inst. Past., Paris, *6*, 1892, 271; *Actinomyces bovis sulphureus* Gasperini, Cent. f. Bakt., *15*, 1894, 684; *Nocardia bovis* Blanchard, in Bouchard, Traité de Path. Générale, *2*, 1896, 857; *Actinomyces sulphureus* Gasperini, Atti Soc. Tosc. Scienz. Nat., P. V., *11*, 1896; *Cladothrix actinomyces* Macé, Traité de Bact., 3rd ed., 1897, 1038; *Streptothrix actinomycotica* Foulerton, Lancet, *2*, 1899, 780; *Streptothrix bovis communis* Foulerton, Jour. Comp. Path. and Therap., *14*, 1901, 50; *Streptothrix bovis* Chester, Man. Determ Bact., 1901, 361; *Streptothrix sulphurea* Caminiti, Cent. f. Bakt., I Abt., Orig., *44*, 1907, 197; *Sphaerotilus bovis* Engler, Syllabus der Pflanzenfam., 5 Aufl., 1907, 5; *Nocardia sulphurea* Vuillemin, Encyclopédie Mycologique, Paris, *2*, 1931, 129; *Proactinomyces bovis* Henrici, Biology of Bact., 2nd ed., 1939, 409.) From Latin *bovis*, of the ox.

Synonyms previous to 1919 as given by Breed and Conn, Jour. Bact., *4*, 1919, 596.

Probable synonym: *Brevistreptothrix spitzi* Lignières, Annales de Parasit., *2*, 1924, 2 (*Streptothrix spitzi* Lignières and Spitz, Cent. f. Bakt., I Abt., Orig., *35*, 1904, 453; *Actinobacterium isreali* var. *spitzi* Sampietro, Ann. Igiene, *18*, 1908, 391; *Discomyces spitzi* Brumpt, Précis de Parasitol., Paris, 1st ed., 1910, 847; *Actinomyces spitzi* Lieske, Morphol. u. Biol. d. Strahlenpilze, Leipzig, 1921, 32; *Oospora spitzi* Sartory, Champ. Paras. Homme et Anim., 1923, 775). Found in mycosis of the upper jaw of oxen in Argentina.

Description from Erikson, Med. Res. Council, London, Special Report Ser. 240, 1940, 63 pp.

No aerial hyphae. Radiate, sulfur-colored granules occur in the pus found in cases of actinomycosis. Large club-shaped hyphae are seen in morbid tissues. Gram-positive. Non-motile. Not acid-fast.

Mycelium: Undergoes fragmentation very rapidly, extensive branching is rare. Hyphae less than 1 micron in diameter.

Colonies: Smoother and softer in consistency, and more uniform than in the following species. The colonies are not adherent to the medium and growth is scantier.

Semi-solid media: Excellent growth, especially with paraffin seal.

Gelatin: Occasionally scant, flaky growth. No liquefaction.

Liquid media: Occasional turbidity with a light flocculent growth.

Acid from glucose, sucrose and maltose. No acid from salicin and mannitol.

Pigments: No soluble pigments produced on protein media. No insoluble pigments produced by growth.

Egg or serum media: No proteolytic action.

Litmus milk: Becomes acid but usually no coagulation, no peptonization. Sometimes no growth.

No hemolysis in blood broth or blood agar.

Serology: No cross agglutination between five bovine strains and human strains of *Actinomyces israeli*. No cross reactions with representative aerobic strains.

Optimum temperature 37°C.

Anaerobic to microaerophilic. Bovine strains are more oxygen-tolerant on egg or serum media than strains of human origin belonging to the following species.

As pointed out by Lignières and Spitz (Bull. Soc. cent. Méd. vet., *20*, 1902, 487 and 546) and others, distinction should be made between the infections produced by *Actinomyces bovis* and those produced by the Gram-negative *Actinobacillus* now known as *Actinobacillus lignieresi*. These infections frequently occur in mixed form and are also frequently complicated by the presence of pyogenic cocci (Magnussen, Acta path. Microbiol. Scand., *5*, 1928, 170; and others).

Source: Originally found in lumpy jaw of cattle.

Habitat: Frequently found in and about mouth of cattle and probably other animals. Lesions may also be produced in the liver, udder or other organs of cattle and hogs. Possibly also in human mouth (Naeslund, Acta path. Microbiol. Scand., *2*, 1925, 110).

This and the following species are sometimes regarded as being identical (see Emmons, Public Health Repts., U.S.P.H.S., *53*, 1935, 1967; Rosebury, Bact. Rev., *8*, 1944, 190; and others).

2. **Actinomyces israeli** (Kruse) Lachner-Sandoval. (Strahlenpilz, Wolff and Israel, Arch. f. path. Anat., *126*, 1891, 11; *Streptothrix israeli* Kruse, in Flügge, Die Mikroorganismen, 3 Aufl., *2*, 1896, 56; *Actinomyces israeli* Lachner-Sandoval, Inaug. Diss., Strassburg, 1898, 64; *Discomyces israeli* Gedoelst, Les champignons parasites de l'homme et des animaux domestiques, 1902, 163; *Actinobacterium israeli* Sampietro, Ann. d'Ig. sperim., *18*, 1908, 331; *Cohnistreptothrix israeli* Pinoy, Bull. Inst. Pasteur, Paris, *11*, 1913, 931; *Nocardia israeli* Castellani and Chalmers, Man. Trop. Med., 2nd ed., 1913, 814; *Anaeromyces bronchitica* Castellani, Douglas and Thomson, Jour. Trop. Med. Hyg., *24*, 1921, 149; *Cohnistreptothrix bronchitica* Verdun and Mandoul, Précis Parasitol., 1924, 754; *Brevistreptothrix israeli* Lignières, Annales de Parasit., *2*, 1924, 2; *Proactinomyces israeli* Negroni, Compt. rend. Soc. Biol., Paris, *117*, 1934, 1239; *Corynebacterium israeli* Haupt and Zeki, Cent. f. Bakt., I Abt., Orig., *130*, 1933, 95; *Oospora israeli*, quoted from Nannizzi,

Tratt. Micopat. Umana, *4*, 1934, 53; *Actinomyces wolff-israel* Lentze, Cent. f. Bakt., I Abt., Orig., *141*, 1938, 21.) Named for Prof. Israel, one of the original isolators of this organism.

Synonyms previous to 1919 essentially as given by Breed and Conn, Jour. Bact., *4*, 1919, 597.

Description from Erikson, Med. Res. Council, London, Special Rept. Ser. 240, 1940, 63 pp.

Erect aerial hyphae produced in an atmosphere of reduced oxygen tension. These hyphae are occasionally septate but no definite spores are formed. One micron or more in diameter. Large club-shaped forms are seen in morbid tissues. Gram-positive. Non-motile. Not acid-fast.

Substrate mycelium: Initially unicellular and the branches may extend into the medium in long filaments or may, more or less quickly, exhibit fragmentation and characteristic angular branching. The latter resembles the similar phenomenon found in *Corynebacterium.*

Colonies: These exhibit a considerable degree of polymorphism but no stable variants have been established. Tougher in texture than those of *Actinomyces bovis.* Old colonies warted in appearance. Adherent to the medium.

Gelatin: Occasionally scant, flaky growth. No liquefaction.

Liquid media: Usually clear.

Acid from sugars: According to Slack (Jour. Bact., *43*, 1941, 193–209) acid from glucose, maltose, mannitol, sucrose and lactose; according to Negroni and Bonfiglioli (Physics, *15*, 1939, 159) acid from glucose, galactose, lactose, fructose, maltose, raffinose, sucrose and xylose.

Pigments: No soluble pigments on protein media. No insoluble pigments produced by growth.

Egg or serum media: No proteolytic action.

Litmus milk: Becomes acid but usually does not clot. No peptonization. Frequently no growth.

No hemolysis.

Serology: No cross agglutination between 12 human strains and bovine strains of *Actinomyces.* No cross reactions with representative aerobic strains.

Optimum temperature 37°C.

Anaerobic to microaerophilic.

Source: From 2 cases of human actinomycosis: (1) A retromaxillary tumor, (2) actinomycosis of lung and breast (Wolff and Isreal).

Habitat: From human sources (mouth, tonsillar crypts, etc.). Also reported from various domestic animals such as dogs (Baudet, Ann. Parasit., *12*, 1934, 296) and cats (Edington, Vet. Record., *14*, 1934, 311).

Appendix: The following names have been applied to anaerobic or semi-anaerobic species, with descriptions which do not permit clear separation from the above or from each other.

Actinobacterium meyeri Prévot. (Anaerobe Streptothrix-Art, Meyer, Cent. f. Bakt., I Abt., Orig., *60*, 1911, 75; Prévot, Ann. Inst. Past., *60*, 1938, 303.) From fetid pus.

Actinomyces discofoliatus Grüter. (Grüter, Ztschr. f. Augenheilk., *13*, 1933, 477; redescribed by Negroni, Mycopathologia, *1*, 1938, 81.) From lachrymal concretion and human infection.

Actinomyces lanfranchii Sani. (Sani, 1916, quoted from Dodge, Medical Mycology, St. Louis, 1935, 731; *Nocardia lanfranchii* de Mello and Pais, Arq. Hig. Pat. Exot., *6*, 1918, 178.) From glandular and ganglionar actinomycosis of the ox. Regarded as a variety of *Actinomyces bovis.*

Actinomyces thjoettae Dodge. (*Cohnistreptothrix sp.* or *Streptothrix sp.* Thjøtta and Gundersen, Jour. Bact., *10*, 1925, 1; Dodge, Medical Mycology, 1935, 713.) From the blood in a case of acute rheumatism.

Cohnistreptothrix neschezadimenki (sic) Chalmers and Christopherson. (Eine Streptothrix, Neschezadimenko, Cent. f. Bakt., I Abt., Orig., *46*, 1908, 573; Chalmers and Christopherson, Ann. Trop. Med., *10*, 1916, 273; *Actinomyces neschczadimenki* Dodge, Medical Mycology, 1935, 712; *Actinobacterium abscessus* Prévot, Ann. Inst. Past., *60*, 1938, 303.) From a human infection.

Discomyces carougeaui Gougerot. (Gougerot, Compt. rend. Soc. Biol., Paris, *67*, 1909, 580; *Nocardia carougeaui* Castellani and Chalmers, Man. Trop. Med., 2nd ed., 1913, 817; *Cohnistreptothrix carogeanui* (sic) Chalmers and Christopherson, Ann. Trop. Med., *10*, 1916, 273; *Streptothrix carougeaui* Greco, Origine des Tumeurs, 1916, 724; *Actinomyces carougeaui* Brumpt, Précis de Parasitol., 4th ed., 1927, 1206.) From a human infection.

Discomyces thibiergei Ravaut and Pinoy. (Ravaut and Pinoy, Ann. Derm. et Syph., *10*, 1909, 417; *Nocardia thibiergei* Castellani and Chalmers, Man. Trop. Med., 2nd ed., 1913, 817; *Cohnistreptothrix thibiergei* Pinoy, Bull. Inst. Past., *11*, 1913, 938; *Oospora thibiergei* Sartory, Champignons Parasites de l'Homme et des Animaux, Fasc. 11, 1923, 792; *Actinomyces thibiergei* Greco, Origine des Tumeurs, 1916, 723.) From a human infection.

Streptothrix cuniculi Schmorl. (Schmorl, Deutsch. Ztschr. f. Thiermed., *17*, 1891, 375; *Actinomyces cuniculi* Gasperini, Ann. Ist. Ig. sper. Univ. Roma, *2*, 1892, 222; *Cladothrix cuniculi* Macé, Traité de Bact., 6th ed., *2*, 1913, 753; *Cohnistreptothrix cuniculi* Chalmers and Christopherson, Ann. Trop. Med., *10*, 1916, 273; *Nocardia cuniculi* Froilani de Mello and Fernandes, Mem. Asiatic Soc. Bengal, 7, 1919, 107; *Oospora cuniculi* Sartory, Champignons parasites de l'Homme et des Animaux, Fasc. 11, 1923, 824.) From infections in rabbits. Generally regarded as probably identical with *Spherophorus necrophorus* (Flügge) Prévot. See page 678.

FAMILY III. STREPTOMYCETACEAE WAKSMAN AND HENRICI.*

(Jour. Bact., *46*, 1943, 339.)

Vegetative mycelium not fragmenting into bacillary or coccoid forms. Conidia borne on sporophores. Primarily soil forms, sometimes thermophilic in rotting manure. A few species are parasitic.

Key to the genera of family **Streptomycetaceae.**

I. Conidia produced in aerial hyphae in chains.

Genus I. *Streptomyces*, p. 929.

II. Conidia produced terminally and singly on short conidiophores.

Genus II. *Micromonospora*, p. 978.

Genus I. **Streptomyces** *Waksman and Henrici.*

(*Streptothrix* Cohn, Beitr. zur Biol. der Pflanzen, *1*, Heft 3, 1875, 186; not *Streptothrix* Corda, Prachtflora Europaescher Schimmelbildung, 1839; *Nocardia* Wright, Jour. Med. Research, *13*, 1905, 349; *Nocardia* Winslow et al., Jour. Bact., *2*, 1917, 554; not *Nocardia* Trevisan, I generi e le specie delle Batteriacee, 1889, 9; *Cohnistreptothrix* (Group I) Ørskov, Investigations in the Morphology of the Ray Fungi. Copenhagen, 1923, 147; not *Cohnistreptothrix* Pinoy, in Liégard and Landrieu, Bull. Soc. Opht., *24*, 1911, 253 and Bull. Inst. Past., *11*, 1913, 929; *Aerothrix* Wollenweber (in part), Ber. deut. Bot. Gesel., *39*, 1921, 26; *Euactinomyces* Langeron (in part), Nouv. Traité de Méd., *4*, 1922; Waksman and Henrici, Jour. Bact., *46*, 1943, 339.)

Organisms growing in the form of a much-branched mycelium with a typical aerial mycelium. Conidiospores formed in chains. Aerobic. Saprophytic soil forms, less commonly parasitic on plants or animals.

This genus can be divided, on the basis of the structure of sporulating hyphae, into five groups:

Group 1. Straight sporulating hyphae, monopodial branching, never producing regular spirals.

Group 2. Spore-bearing hyphae arranged in clusters.

Group 3. Spiral formation in aerial mycelium; long, open spirals.

Group 4. Spiral formation in aerial mycelium; short, compact spirals.

Group 5. Spore-bearing hyphae arranged on mycelium in whorls or tufts.

The type species is *Streptomyces albus* (Rossi Doria *emend.* Krainsky) Waksman and Henrici.

Key to the species of genus **Streptomyces.**

I. Saprophytes; psychrophilic to mesophilic.
   A. Soluble pigment on organic media faint brown, golden-yellow, or blue; pigment may also be absent entirely.
      1. Pigment absent, or faint brown pigment formed at first and later lost; aerial mycelium abundant, white.

         1. *Streptomyces albus.*

      2. Pigment blue or red, when present. The red (insoluble) phase occurs when the reaction is distinctly acid, the blue (soluble) phase when it is alkaline.

         2. *Streptomyces coelicolor.*

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* Revised by Prof. S. A. Waksman, New Jersey Experiment Station, New Brunswick, New Jersey and Prof. A. T. Henrici, University of Minnesota, Minneapolis, Minnesota, May, 1943.

3. Pigment at first green becoming brown; aerial mycelium usually absent.
   3. *Streptomyces verne.*
4. Pigment yellowish-green; growth on synthetic agar penetrating into medium, pink.
   4. *Streptomyces californicus.*
5. Pigment golden-yellow; growth on synthetic agar yellow, with yellow soluble pigment.
   5. *Streptomyces flaveolus.*
6. Pigment brown (only on certain protein media, as gelatin, glucose broth).
   a. Grown on synthetic agar red to pink. Scant, white aerial mycelium.
      6. *Streptomyces bobiliae.*
   aa. Growth on synthetic agar colorless; aerial mycelium thin, rose-colored.
      7. *Streptomyces roseochromogenus.*
   aaa. Growth on synthetic agar mouse-gray; powdery aerial mycelium.
      8. *Streptomyces griseolus.*
   aaaa. Growth on synthetic agar white turning yellowish, aerial mycelium white.
      9. *Streptomyces erythreus.*

B. Soluble yellow pigment on Ca-malate agar.
1. Proteolytic action strong in milk and gelatin.
   a. Yellow pigment formed.
      b. Cellulose decomposed; starch is hydrolyzed.
         10. *Streptomyces cellulosae.*
      bb. Cellulose not decomposed.
         11. *Streptomyces parvus.*
2. Proteolytic action weak.
   12. *Streptomyces malenconi.*

C. Soluble brown pigment formed on synthetic agar.
1. Yellowish-green pigment on potato.
   13. *Streptomyces diastaticus*
2. Red-brown pigment on potato plug.
   14. *Streptomyces fimicarius.*

D. Greenish-yellow soluble pigment formed; sulfur-yellow pigment on potato.
   15. *Streptomyces flavovirens.*

E. Soluble brown pigment formed in all media containing organic substances.
1. Pigment deep brown (chromogenic type).
   a. Pigment faint brown on organic media, becoming greenish-brown to black; reddish aerial mycelium on glucose agar.
      16. *Streptomyces olivochromogenus.*
   aa. Aerial mycelium yellowish with gray margin; weak diastatic action.
      17. *Streptomyces diastatochromogenes.*
   aaa. Aerial mycelium yellowish; diastatic action weak.
      18. *Streptomyces flavochromogenes.*
   aaaa. Aerial mycelium gray; sporophores in clusters; strongly antibiotic.
      19. *Streptomyces antibioticus.*

2. Growth and aerial mycelium green on synthetic agar.
   20. *Streptomyces viridochromogenes.*
3. Deep brown to black pigment on synthetic agar.
   a. Orange-red on potato; no aerial mycelium on synthetic agar; growing feebly.
      21. *Streptomyces purpeochromogenus.*
   aa. Brown to black on potato; abundant cottony aerial mycelium on synthetic agar.
      b. Brown ring on milk culture; coagulated; peptonized.
         22. *Streptomyces phaeochromogenus.*
      bbb. Black ring on milk; no coagulation; peptonization doubtful.
         23. *Streptomyces aureus.*
         c[1]. Red to rose-red pigment on glucose, maltose, and starch agar.
            24. *Streptomyces erythrochromogenes.*
         c[2]. Lavender-colored aerial mycelium.
            25. *Streptomyces lavendulae.*
         c[3]. Growth on potato gray with black center.
            26. *Streptomyces reticuli.*
         c[4]. Growth on potato cream-colored, becoming pink to dark red.
            27. *Streptomyces rubrireticuli.*
         c[5]. Growth on potato greenish-olive.
            d. Aerial mycelium straw-colored.
               28. *Streptomyces flavus.*
            dd. Aerial mycelium chrome-orange.
               29. *Streptomyces ruber.*

F. No soluble pigment formed on gelatin or other media.
1. Proteolytic action strong in milk and gelatin.
   a[1]. Yellowish-green growth on starch with pinkish aerial mycelium.
      30. *Streptomyces citreus.*
   a[2]. Golden-yellow growth, later becoming orange to red-brown, on synthetic media.
      31. *Streptomyces fulvissimus.*
   a[3]. Cream-colored growth on starch media.
      32. *Streptomyces gougeroti.*
   a[4]. Bluish-black color on synthetic media, with white aerial mycelium.
      33. *Streptomyces violaceoniger.*
   a[5]. Yellowish pigment on potato.
      b. Aerial mycelium thick, powdery, water-green; starch is hydrolyzed.
         34. *Streptomyces griseus.*
      bb. Aerial mycelium white; starch weakly hydrolyzed.
         35. *Streptomyces griseoflavus.*
   a[6]. Greenish-black pigment on potato; aerial mycelium white.
      36. *Streptomyces albidoflavus.*
   a[7]. Reddish-brown pigment on potato; aerial mycelium white; starch is not hydrolyzed.
      37. *Streptomyces poolensis.*

a⁸. Gray to sulfur-yellow pigment on potato.
b. Aerial mycelium mouse-gray to light drab; starch is hydrolyzed.
38. *Streptomyces olivaceus.*
bb. Aerial mycelium yellowish-white.
39. *Streptomyces lieskei.*
bbb. No aerial mycelium; starch is hydrolyzed.
40. *Streptomyces microflavus.*
a⁹. No soluble pigment on potato.
41. *Streptomyces cacaoi.*

2. Proteolytic action weak.
a. Soluble pigment formed on synthetic agar.
b. Pigment blue or blue-black.
42. *Streptomyces novaecaesareae.*
bb. Pigment brown to black.
43. *Streptomyces exfoliatus.*
44. *Streptomyces gelaticus.*
aa. No soluble pigment on synthetic agar.
b¹. Growth turning black; diastatic action strong.
c. Growth on synthetic agar scant with abundant spirals in aerial mycelium.
45. *Streptomyces rutgersensis.*
cc. No spirals on synthetic agar; characteristic green-colored growth on protein-glycerol medium.
46. *Streptomyces lipmanii.*
ccc. No spirals on synthetic agar; growth dark, almost black.
47. *Streptomyces halstedii.*
b². Moist aerial mycelium, many spirals.
48. *Streptomyces hygroscopicus.*
b³. Growth orange-colored.
49. *Streptomyces fradiae.*
b⁴. Growth yellowish.
50. *Streptomyces alboflavus.*
b⁵. Growth rose to red; aerial mycelium white.
51. *Streptomyces albosporeus.*
b⁶. Growth cream-colored; aerial mycelium flaky.
52. *Streptomyces flocculus.*
b⁷. Growth red; aerial mycelium black.
c. Complete decomposition of cellulose; weakly diastatic.
53. *Streptomyces melanosporeus.*
cc. Incomplete decomposition of cellulose; strongly diastatic.
54. *Streptomyces melanocyclus.*

3. No proteolytic action or very little.
a. Acid-resistant strains.
55. *Streptomyces acidophilus.*
aa. Non-acid-resistant.
56. *Streptomyces rubescens.*

II. Saprophytes; thermophilic.
  A. Starch hydrolyzed. Yellowish growth on potato.
    57. *Streptomyces thermophilus.*
  B. Starch not hydrolyzed. Abundant, dark-colored growth on potato.
    58. *Streptomyces thermofuscus.*

III. Plant parasites.
  A. Tyrosinase reaction positive; aerial mycelium gray-white.
    59. *Streptomyces scabies.*
  B. Tyrosinase reaction negative; attacks sweet potatoes.
    60. *Streptomyces ipomoea.*

IV. Isolated from animal tissues. In the animal body, hyphae often show clavate enlargements at the ends.
  A. Limited proteolytic action in gelatin, milk, coagulated egg-albumin or fibrin.
    1. Color of vegetative growth golden-brown.
      61. *Streptomyces fordii.*
    2. Color of vegetative growth pink.
      a. Sparse white aerial mycelium.
        62. *Streptomyces africanus.*
      aa. Formation on mycelium of bodies similar to *Thermoactinomyces.*
        63. *Streptomyces gallicus.*
      aaa. Yellowish-pink growth on potato plug; scant white aerial mycelium.
        64. *Streptomyces pelletieri.*
    3. Color of vegetative growth white.
      65. *Streptomyces listeri.*
    4. Vegetative growth cream-colored, scant white aerial mycelium.
      66. *Streptomyces upcottii.*
    5. Growth very limited on various media, except on potato plug; no liquefaction of gelatin.
      67. *Streptomyces hortonensis.*
  B. Strong proteolytic action in gelatin and milk.
    1. No pigment produced.
      a^1. No growth on potato plug.
        68. *Streptomyces gibsonii.*
      a^2. Moist, membranous growth on potato plug; diastase formed.
        69. *Streptomyces beddardii.*
        70. *Streptomyces kimberi.*
      a^3. Extensive growth on potato media; white powdery aerial mycelium.
      a^4 Abundant growth on potato plug, becoming black; white-gray aerial mycelium; plug discolored.
        71. *Streptomyces somaliensis.*
      a^5. Pink-colored growth on some media.
        72. *Streptomyces panjae.*
      a^6. Profuse white aerial mycelium on most media, spiral formation.
        73. *Streptomyces willmorei.*

1. Streptomyces albus (Rossi Doria *emend.* Krainsky) Waksman and Henrici. (*Streptotrix alba* Rossi Doria, Ann. d'Ist. d'Ig. sper. di. Univ. di Roma, *1*, 1891,

399; *Cladothrix alba* Macé, Traité Pratique Bact., 3rd ed., 1897; *Actinomyces albus* Krainsky, Cent. f. Bakt., II Abt., *41*, 1914, 662; *Nocardia alba* Chalmers and Christopherson, Ann. Trop. Med. and Parasit., *10*, 1916, 270; Waksman and Henrici, Jour. Bact., *46*, 1943, 339.) From Latin *albus*, white.

Additional synonyms as given by Baldacci (Mycopathologia, *2*, 1940, 156): *Cladothrix dichotoma* Macé, not Cohn, 1886; *Streptothrix foersteri* Gasperini, not Cohn, 1890; *Streptothrix No. 2* and *3*, Almquist, 1890; *Actinomyces saprophyticus* Gasperini, 1892; *Oospora doriae* Sauvageau and Radais, 1892; *Cladothrix liquefaciens* Hesse, 1892 (according to Duché); *Cladothrix invulnerabilis* Acosta and Grande Rossi, 1893; *Actinomyces chromogenus* Gasperini, 1894 (*Streptotrix nigra* Rossi Doria, 1891); *Streptothrix gedanensis I* Scheele and Petruschky, 1897; *Streptothrix gramine-arum* Berestneff, 1898; *Actinomyces thermophilis* (Berestneff) Miehe, not Gilbert, 1898; *Cladothrix odorifera* Rullmann, 1898; *Actinomyces chromogenes* Gasperini *β alba* Lehmann and Neumann, 1899; *Oospora sp.* Bodin, 1899 (according to Duché); *Oospora alpha* Price-Jones, 1900 (according to Chalmers and Christopherson); *Streptothrix leucea* Foulerton, 1902 (according to Chalmers and Christopherson); *Streptothrix candida* Petruschky, 1903; *Streptothrix lathridii* Petruschky, 1903; *Streptothrix dassonvillei* Brocq-Rousseau, 1907 (according to Duché); *Streptothrix pyogenes* Caminiti, 1907 (according to Chalmers and Christopherson); *Streptothrix sanninii* Ciferri, 1922; *Actinomyces almquisti* Duché, 1934; *Actinomyces gougeroti* Duché, 1934. Doubtful synonyms: *Oospora metchnikowi* Sauvageau and Radais, 1892; *Oospora guignardi* Sauvageau and Radais, 1892; *Actinomyces albus* Waksman and Curtis, 1919; *Actinomyces thermodiastaticus* Bergey, (1919) 1925. Varieties: *Actinomyces albus* var. *acidus* Neukirch, 1902 (according to Nannizzi); *Actinomyces albus* var. *ochroleucus* Neukirch, 1902 (according to Wollenweber); *Actinomyces albus* var. *toxica* Rossi, 1905; *Actinomyces albus* var. *cretaceus* (Krüger) Wollenweber, 1920; *Actinomyces albus* var. *α* Ciferri, 1927.

More complete information regarding these species will be found in the text or in the Appendix to Genus *Streptomyces*.

The description of this species by Rossi Doria is incomplete. The characters given below are taken from Krainsky (*loc. cit.*) with some supplementary information from later authors. Other descriptions which may vary from this in certain details are given by Waksman and Curtis (Soil Sci., *1*, 1916, 117), Bergey et al. (Manual, 1st ed., 1923, 367), Duché (Les actinomyces du groupe albus, Paris, 1934, 257) and Baldacci (*loc. cit.*).

Vegetative hyphae: Branched, 1 micron in diameter.

Aerial mycelium: Abundant, white. Hyphae 1.3 to 1.7 microns in diameter with ellipsoidal spores (1 micron long) in coiled chains on lateral branches of the aerial hyphae.

Gelatin: Liquefaction. Colonies gray, no soluble pigment.

Ca-malate agar: Colonies of medium size, the center only is covered with a white aerial mycelium.

Starch agar: Aerial mycelium white but covers the whole surface.

Glucose agar: Gray aerial mycelium becoming brownish.

Peptone and bouillon agar: No aerial mycelium but a chalky white deposit forms on old colonies.

Odor: Earthy or musty.

Broth: Flaky growth on bottom with surface pellicle in old cultures.

Potato: Colonies and aerial mycelium white.

Carrots and other vegetables: Excellent growth (Duché).

No growth on cellulose.

No hydrolysis of starch.

Actively proteolytic.

Nitrites produced from nitrates.

Milk: Peptonized after coagulation. Reaction becomes alkaline (Duché).

Aerobic.

Source: From air and soil (Rossi Doria); from garden soil (Krainsky).

Habitat: Dust, soil, grains and straw. Widely distributed.

2. **Streptomyces coelicolor** (Reiner-Müller) *comb. nov.* (*Streptothrix coelicolor* Reiner-Müller, Cent. f. Bakt., I Abt., Orig., *46*, 1908, 197; *Nocardia coelicolor* Chalmers and Christopherson, Ann. Trop. Med. and Parasit., *10*, 1916, 271; *Actinomyces coelicolor* Lieske, Morphol. u. Biol. d. Strahlenpilze, Leipzig, 1921, 28.) From Latin *caelum*, sky and *color*, color.

Regarded by the authors of this section as the same as *Actinomyces violaceus* Waksman and Curtis, Soil Science, *1*, 1916, 110 (*Actinomyces violaceus-ruber* Waksman and Curtis, *ibid.*, 127; *Actinomyces waksmanii* Bergey et al., Manual, 3rd ed., 1930, 489) and *Actinomyces tricolor* Wollenweber, Arbeiten d. Forschungsinstitut für Kartoffelbau, 1920, 13. It is, however, pointed out by J. E. Conn (Jour. Bact., *46*, 1943, 133) that certain differences between the descriptions of Waksman and Curtis, and that of Müller may correspond to actual chemical differences in the pigments produced; and that the organism of Waksman and Curtis may be a separate species.

Description by Müller except as noted.

Morphology of *Streptomyces coelicolor* has not been fully described. According to Waksman and Curtis who described *Actinomyces violaceus-ruber*, this is as follows: Straight filaments with open, dextrorse spirals, breaking up into conidia. Conidia oval or rod-shaped, 0.7 to 1.0 by 0.8 to 1.5 microns.

Gelatin: Good growth. No pigment formation. Liquefaction fairly rapid, beginning in 4 to 7 days.

Plain agar: Good growth. Pigment lacking or faint blue (Conn).

Czapek agar (according to Waksman and Curtis concerning *Actinomyces violaceus-ruber*): Thin, spreading, colorless at first, becoming red, then blue. Aerial mycelium thin, white, powdery, becoming mouse-gray.

Asparagine agar (synthetic): With glycerol as source of carbon, good growth, violet to deep blue, with pigment diffusing through medium; final H-ion concentration about pH 7.0 to 8.0. With glucose as source of carbon, poorer growth, red, no diffusion of pigment; final H-ion concentration about pH 6.0 to 5.0 (Conn).

Broth: Good growth. Cretaceous layer around edge.

Milk: No change at 25°C (Conn). At 37°C, coagulation. Peptonization beginning in 3 to 5 days.

Potato: Strong pigment production, sometimes greenish-blue or violet, but usually sky-blue, diffusing through medium and coloring water at base of tube.

Nitrites produced from nitrates.

Blood agar: Hemolysis showing on 4th day.

Müller reports no acid from carbohydrates on organic media. Conn, however, finds acid from glucose and lactose, and sometimes from sucrose and mannitol when grown on synthetic media.

Pigment: The most striking characteristic of this organism is a litmus-like pigment usually produced on potato or synthetic media, which is deep blue and water-soluble at alkaline reactions (beyond pH 8.0), violet around neutrality, and red (insoluble in water) at about pH 6.0. Conn points out that the primary pigment has a spectrophotometric curve almost identical with that of azolitmin; but that there are undoubtedly other pigments produced, especially in the case of the strains believed to be typical of *Actinomyces violaceus-ruber* (as previously pointed out by Waksman and Curtis).

Good growth at room temperature and at 37°C.

Aerobic.

Distinctive character: Litmus-like pigment.

Source: Dust contamination on a potato slant.

Habitat: Soil and plant surfaces. Very abundant.

NOTE: Because of the numerous colors and shades shown by the pigment according to final H-ion concentration and other less understood factors, this species may have been described under various names. On the other hand, it is entirely possible, as pointed out by Conn (*loc. cit.*), that careful study of the pigments may show that more than one species is actually involved.

3. **Streptomyces verne** (Waksman and Curtis) *comb. nov.* (*Actinomyces verne* Waksman and Curtis, Soil Science, *1*, 1916, 120.) Derivation uncertain.

Filaments with close branching of the hyphae. No conidia demonstrated.

Gelatin stab: Small, cream-colored colonies. Rapid liquefaction.

Synthetic agar: Abundant, spreading, wrinkled, elevated, glossy, yellowish growth, becoming brownish, lichenoid margin.

Starch agar: Scant, brownish, restricted growth.

Glucose agar: Abundant, much folded growth, center raised, gray with purplish tinge, entire.

Plain agar: Small, grayish colonies with depressed center, becoming wrinkled.

Glucose broth: Slightly flaky sediment.

Litmus milk: Pinkish-brown ring; coagulated; peptonized, with alkaline reaction.

Potato: Cream-colored growth, becoming gray, wrinkled.

Nitrites produced from nitrates.

Soluble brown pigment formed. Soluble green pigment produced when freshly isolated.

Starch is hydrolyzed.

Aerobic.

Optimum temperature 37°C.

Source: Isolated once from upland California soil.

Habitat: Soil.

4. **Streptomyces californicus** (Waksman and Curtis) *comb. nov.* (*Actinomyces californicus* Waksman and Curtis, Soil Science, *1*, 1916, 122.) Named for the State of California.

Filaments with long, narrow, open spirals. Spherical to oval conidia from straight and spiral hyphae.

Gelatin stab: Gray, moist, abundant surface growth. Liquefaction in 30 days.

Synthetic agar: Spreading, vinaceous-colored growth. Aerial mycelium powdery, thin, light neutral gray.

Starch agar: Growth spreading, pink center with colorless to gray margin.

Glucose agar: Restricted, much folded, cream-colored growth, with sulfur-yellow tinge.

Plain agar: Thin, restricted, yellowish to cream-colored growth.

Glucose broth: Solid cream-colored mass on surface, with pink tinge.

Litmus milk: Faint, brownish surface growth; coagulated; peptonized in 40 days.

Potato: Glossy, yellow to red growth, turning red-brown.

Nitrites produced from nitrates.

No soluble pigment formed.

Starch is hydrolyzed.

Aerobic.

Optimum temperature 37°C.

Source: Isolated once from California sandy loam.

Habitat: Soil.

5. **Streptomyces flaveolus** (Waksman) *comb. nov.* (Actinomyces 168, Waksman, Soil Science, *8*, 1919, 134; *Actinomyces flaveolus* Waksman, in Manual, 1st ed., 1923, 368; *Actinomyces heimi* Duché, Actinomyces du groupe albus. Encyclopédie Mycologique, Paris, *6*, 1934, 359.) From Latin *flavus*, yellow and *eolus*, diminutive ending; hence, somewhat yellow.

Numerous closed and open spirals on all media. Conidia oval to elliptical.

Gelatin stab: Liquefied; abundant, yellowish, spreading pellicle.

Synthetic agar: Growth light sulfur-yellow turning to cadmium-yellow, penetrating deep into medium. Aerial mycelium as white to ash-gray patches.

Starch agar: White, spreading growth.

Glucose agar: Restricted growth, surface folded, raised.

Plain agar: White, glistening, wrinkled growth.

Glucose broth: Thin, yellow pellicle.

Litmus milk: Sulfur-yellow ring; coagulated; peptonized, with faintly alkaline reaction.

Potato: Abundant, wrinkled, cream-colored growth.

Nitrites produced from nitrates.

Soluble empire-yellow pigment formed.

Starch is hydrolyzed.

Aerobic.

Optimum temperature 25°C.

Habitat: Soil.

6. **Streptomyces bobiliae** (Waksman and Curtis) *comb. nov.* (*Actinomyces bobili* Waksman and Curtis, Soil Science, *1*, 1916, 121.) From the name of a person.

Mycelium with branching hyphae. Few close spirals of a dextrorse type.

Gelatin stab: Dense, cream-colored to brownish surface growth. Rapid liquefaction.

Synthetic agar: Abundant, glossy, wrinkled, elevated, coral-red growth becoming deep red. Scant, white aerial mycelium.

Starch agar: Restricted, finely wrinkled, coral-red growth with hyaline margin.

Plain agar: Restricted, glossy, gray growth, becoming brownish.

Glucose broth: Round colonies in fluid. Flaky sediment.

Litmus milk: Dark brown ring. No coagulation. Peptonized.

Potato: Thin, yellowish growth, becoming red, dry and wrinkled.

Nitrites produced from nitrates.

Soluble brown pigment formed.

Starch is hydrolyzed.

Aerobic.

Optimum temperature 37°C.

Source: Isolated once from adobe and garden soils.

Habitat: Soil.

7. **Streptomyces roseochromogenus** (Jensen) *comb. nov.* (*Actinomyces roseus* Krainsky, Cent. f. Bakt., II Abt., *41*, 1914, 662; Waksman and Curtis, Soil Science, *1*, 1916, 125; Waksman, Soil Science, *8*, 1919, 148; not *Actinomyces roseus* Namyslowski, Cent. f. Bakt., I Abt., Orig., *62*, 1912, 567; *Nocardia rosea* Chalmers and Christopherson, Ann. Trop. Med. and Parasit., *10*, 1916, 270; *Actinomyces roseochromogenus* Jensen, Proc. Linnean Soc. New So. Wales, *56*, 1931, 359.) From Latin, producing rose color.

Filaments with numerous open and closed spirals. Conidia 1.0 to 1.2 by 1.5 to 3.0 microns.

Gelatin stab: Liquefaction, with small, cream-colored colonies in bottom of liquid.

Synthetic agar: Thin, spreading, colorless growth. Aerial mycelium thin, pale, brownish.

Starch agar: Colorless, spreading growth.

Glucose agar: Growth extensive, spreading, colorless, entire.

Plain agar: White growth, becoming yellowish.

Glucose broth: Cream-colored ring, with flaky sediment.

Litmus milk: Brownish ring. No coagulation. Peptonized in 10 to 15 days, becoming strongly alkaline.

Potato: Much wrinkled, brownish growth.

Nitrites produced from nitrates.

Purple pigment on egg media; brown on gelatin.

Starch is hydrolyzed.

Aerobic.

Optimum temperature 37°C.
Habitat: Soil.

8. **Streptomyces griseolus** (Waksman) *comb. nov.* (Actinomyces 96, Waksman, Soil Science, *8*, 1919, 121; *Actinomyces griseolus* Waksman, in Manual, 1st ed., 1923, 369.) From Latin *griseus*, gray and *eolus*, diminutive ending; hence, somewhat gray.

Branching mycelium; no spirals observed. Conidia spherical or oval-shaped.

Gelatin stab: Liquefied with yellowish, flaky pellicle and sediment.

Synthetic agar: Colorless, thin, spreading growth, chiefly in the medium; surface growth limited almost entirely to the aerial mycelium. Aerial mycelium at first gray, later becoming pallid, neutral-gray.

Starch agar: Grayish-brown growth, with dark ring.

Glucose agar: Spreading growth, both on the surface and into the medium; center raised, cream-colored, turning dark.

Plain agar: Brownish growth, with smooth surface.

Glucose broth: Thick, brown ring.

Litmus milk: Abundant growth, pink pellicle; coagulated; peptonized, becoming alkaline.

Potato: Cream-colored growth, becoming black, spreading.

Nitrites produced from nitrates.

Faint brownish soluble pigment formed.

Starch is hydrolyzed.

Aerobic.

Optimum temperature 25°C.

Habitat: Soil.

9. **Streptomyces erythreus** (Waksman) *comb. nov.* (Actinomyces 161, Waksman, Soil Science, *8*, 1919, 112; *Actinomyces erythreus* Waksman, in Manual, 1st ed., 1923, 370; *Actinomyces krainskii* Duché, Encyclopédie Mycologique, Paris, *6*, 1934, 306.) From Greek *erythrus*, red.

Mycelium fine, branching; numerous open spirals formed as side branches of the main hyphae.

Gelatin stab: Abundant, dense, gray growth with pinkish tinge, chiefly on surface of liquefied medium.

Synthetic agar: Spreading growth with irregular margin, developing deep into the medium; color at first white, later turning yellowish, agar around growth has a white, milky surface. Aerial mycelium, thick, solid, white.

Starch agar: Cream-colored, circular colonies, with faint greenish tinge.

Glucose agar: Abundant, spreading, cream-colored growth, later turning brown chiefly on surface; center raised, lobate margin.

Plain agar: Cream-colored growth.

Glucose broth: Abundant, cream-colored surface growth.

Litmus milk: Yellowish surface zone; coagulated; peptonized, becoming alkaline.

Potato: Wrinkled, cream-colored growth, becoming yellowish.

Nitrites produced from nitrates.

Soluble purple pigment formed.

Starch is hydrolyzed.

Aerobic.

Optimum temperature 25°C.

Similar to *Streptomyces erythrochromogenes* (Species No. 24) except that no brown soluble pigment is formed.

Source: From California and Hawaiian soils.

Habitat: Soil.

10. **Streptomyces cellulosae** (Krainsky) *comb. nov.* (*Actinomyces cellulosae* Krainsky, Cent. f. Bakt., II Abt., *41*, 1914, 662.) From M. L. *cellulosa*, cellulose.

Conidia almost spherical, 1.3 microns in diameter, often arranged in chains.

Gelatin colonies: Circular, yellowish.

Gelatin stab: Liquefied.

Plain agar: White aerial mycelium.

Ca-malate agar: Yellowish colonies;

gray aerial mycelium. Soluble yellow pigment formed.

Glucose agar: Abundant growth, gray aerial mycelium. Soluble yellow pigment.

Starch agar: Same as on glucose agar.

Glucose broth: Coarse, flaky growth. Yellow pigment.

Litmus milk: Peptonized.

Potato: Light gray growth; gray aerial mycelium.

Nitrates show slight reduction.

Strong diastatic action. Esculin is hydrolyzed.

Cellulose is decomposed.

Aerobic.

Optimum temperature 30° to 35°C.

Habitat: Soil.

11. **Streptomyces parvus** (Krainsky) *comb. nov.* (*Actinomyces parvus* Krainsky, Cent. f. Bakt., II Abt., *41*, 1914, 662; *Nocardia parva* Chalmers and Christopherson, Ann. Trop. Med. and Parasit., *10*, 1916, 268.) From Latin *parvus*, small.

Conidia more or less oval, 0.9 to 1.3 by 1.2 to 1.8 microns.

Gelatin: Colonies yellow. Slow liquefaction.

Ca-malate agar: Small, yellow colonies with light yellow aerial mycelium.

Glucose agar: Same as on Ca-malate agar.

Starch agar: Same as on Ca-malate agar.

Glucose broth: Hemispherical colonies in bottom of tube.

Litmus milk: Peptonized.

Nitrate slightly reduced.

Moderate diastatic action.

Cellulose not decomposed.

Aerobic.

Optimum temperature.

Source: Garden soil.

Habitat: Soil.

12. **Streptomyces malenconii** (Duché) *comb. nov.* (*Actinomyces malenconi* Duché, Encyclopédie Mycologique, Paris, *6*, 1934, 353.) Named for Mr. Malençon from whom the original culture was obtained.

Gelatin: Poor growth; liquefaction.

Asparagine glucose agar: Rapid opaque growth, later becoming covered with white aerial mycelium; amber-colored pigment, dissolved in medium.

Peptone agar: Cream-colored lobous growth, covered with whitish aerial mycelium.

Asparagine glucose solution: Long, much branching filaments, 0.5 to 0.7 micron; somewhat heavier aerial mycelium with a few irregular conidia; some flaky growth on bottom of tube; surface growth is cream-colored with rare white aerial mycelium; liquid becomes slightly yellow.

Peptone solution: Whitish growth with yellowish soluble pigment.

Milk: Surface growth with whitish aerial mycelium; slow peptonization, liquid becoming brownish-colored.

Potato: Rapid growth with thin white mycelium; no soluble pigment.

Coagulated serum: Radiating cream-colored growth covered with white aerial mycelium; slow liquefaction.

No pigment on tyrosine medium.

Source: Culture obtained from Mr. Malençon, an inspector in Morocco.

13. **Streptomyces diastaticus** (Krainsky) *comb. nov.* (*Actinomyces diastaticus* Krainsky, Cent. f. Bakt., II Bakt., *41*, 1914, 662; Waksman and Curtis, Soil Science, *1*, 1916, 116.) From M. L. *diastaticus*, diastatic.

Actinomyces roseodiastaticus Duché, Encyclopédie Mycologique, Paris, *6*, 1934, 329 is said to differ from both Krainsky's, and Waksman and Curtis' strains.

Filaments may show fine, long, narrow spirals. Conidia oval, 1.0 to 1.2 by 1.1 to 1.5 microns.

Gelatin stab: Liquefied with small, cream-colored flakes in liquid.

Synthetic agar: Thin, gray, spreading

growth. Aerial mycelium white, becoming drab gray.

Starch agar: Thin, colorless, spreading growth. Aerial mycelium gray.

Glucose agar: Yellowish, spreading growth. No aerial mycelium.

Plain agar: Cream-colored growth. Thin aerial mycelium.

Glucose broth: Gray ring with grayish colonies in bottom of tube.

Litmus milk: Brownish ring; coagulated; peptonized in 25 to 30 days, becoming faintly alkaline.

Potato: Abundant, wrinkled, cream-colored growth with greenish tinge.

Nitrites produced from nitrates.

Brown to dark brown soluble pigment formed.

Starch is hydrolyzed.

Aerobic.

Optimum temperature 37°C.

Habitat: Soil.

14. **Streptomyces fimicarius** (Duché) *comb. nov.* (*Actinomyces fimicarius* Duché, Encyclopédie Mycologique, Paris, *6*, 1934, 346.) From Latin *fimus*, dung and *carus*, loving.

Gelatin: Punctiform colonies with whitish aerial mycelium; reddish soluble pigment. Liquefaction.

Asparagine agar: Cream-colored growth with whitish aerial mycelium; reverse side, cream-colored to slight ochre.

Czapek's agar: Yellowish masses of growth with yellowish-white aerial mycelium; reverse side orange-colored; faint yellowish soluble pigment.

Peptone agar: Cream-colored growth with white aerial mycelium; reverse side, yellowish.

Asparagine solution: Vegetative filaments 0.5 to 0.6 micron long; branching aerial mycelium 0.8 to 1.0 micron, forming numerous conidia; flaky growth produced on bottom; surface growth becomes covered with a white aerial mycelium; reverse side, brownish-red.

Czapek's solution: Cream-colored punctiform growth with yellowish aerial mycelium; no soluble pigment.

Peptone solution: Whitish growth that flakes throughout liquid; yellowish pigment.

Tyrosine medium: White growth with yellowish reverse; yellowish soluble pigment.

Milk: Colorless growth becoming covered with whitish aerial mycelium; slow peptonization of milk which becomes rose-colored, finally changing to brownish-red.

Potato: Cream-colored to yellowish growth with whitish aerial mycelium; reddish-brown pigmentation of plug.

Coagulated serum: Cream-colored growth with whitish aerial mycelium; rapid liquefaction of serum.

Distinctive characters: Abundant growth upon neutral and acid media; whitish aerial mycelium; marked odor; soluble brownish-red pigment. This species seems to form the transition type between the *Actinomyces albus* group and the *Actinomyces chromogenus* group.

Habitat: Found abundantly in manure.

15. **Streptomyces flavovirens** (Waksman) *comb. nov.* (Actinomyces 128, Waksman, Soil Science, *8*, 1919, 117; *Actinomyces flavovirens* Waksman, in Manual, 1st ed., 1923, 352; *Actinomyces alboviridis* Duché, Encyclopédie Mycologique, Paris, *6*, 1934, 317.) From Latin *flavus*, yellow and *virens*, becoming green.

Large masses of minute tufts; the hyphae coarse, straight, short, relatively unbranched, beaded; open spirals may be produced in certain substances. Conidia spherical, oval to rod-shaped, 0.75 to 1.0 by 1.0 to 1.5 microns.

Gelatin stab: Yellowish-green surface pellicle, consisting of a mass of small colonies, on the liquefied medium.

Synthetic agar: Growth spreading deep into the substratum, yellowish with greenish tinge. Aerial mycelium, gray, powdery.

Starch agar: Greenish-yellow, spreading growth, developing deep into the medium.

Glucose agar: Restricted growth, developing only to a very small extent into the medium, yellow, turning black, edge entire.

Plain agar: Yellowish growth; the reverse dark in center with yellowish zone and outer white zone.

Glucose broth: Thick, sulfur-yellow pellicle or ring.

Litmus milk: Cream-colored to brownish ring; coagulated; peptonized, becoming faintly alkaline.

Potato: Sulfur-yellow, wrinkled growth.

Only a trace of nitrite is formed from nitrates.

Greenish-yellow soluble pigment formed.

Starch is hydrolyzed.

Aerobic.

Optimum temperature 25°C.

Habitat: Soil.

16. **Streptomyces olivochromogenus** (Bergey et al.) *comb. nov.* (*Actinomyces chromogenus 205*, Waksman, Soil Science, 8, 1919, 106; *Actinomyces olivochromogenus* Bergey et al., Manual, 2nd ed., 1925, 368.) From Greek, producing an olive color.

Filaments with numerous close spirals. Conidia oval or elliptical.

Gelatin stab: Cream-colored, spreading surface growth. Rapid liquefaction.

Synthetic agar: White, spreading growth. Aerial mycelium ash gray with brownish tinge.

Starch agar: Transparent, spreading growth.

Glucose agar: Abundant, natal brown to almost black growth, entire margin.

Plain agar: Wrinkled, brown growth, becoming gray-green.

Glucose broth: Thin, brown growth, flaky sediment.

Litmus milk: Dark brown ring; coagulated; peptonized, becoming alkaline.

Potato: Small, wrinkled, black colonies.

Faint traces of nitrites formed from nitrates.

Soluble brown pigment formed.

Starch is hydrolyzed.

Aerobic.

Optimum temperature 37°C.

Habitat: Soil.

17. **Streptomyces diastatochromogenes** (Krainsky) *comb. nov.* (*Actinomyces diastatochromogenes* Krainsky, Cent. f. Bakt., II Abt., *41*, 1914, 662.) From Greek, probably intended to mean producing both diastase and color.

Conidia spherical or oval, about 1.2 microns.

Gelatin colonies: Light gray-colored.

Gelatin stab: Liquefied.

Plain agar: Medium-sized colonies, with white to gray aerial mycelium.

Ca-malate agar: Medium-sized colonies, colorless, with gray aerial mycelium.

Glucose agar: Same as on Ca-malate agar.

Starch agar: Same as on Ca-malate agar.

Glucose broth: Flaky colonies in depth at first, later also over surface.

Potato: Light gray colonies; gray aerial mycelium; medium colored black.

Soluble brown pigment formed in gelatin.

Weakly diastatic.

No growth on cellulose.

Tyrosinase formed.

Aerobic.

Optimum temperature 35°C.

Habitat: Soil.

18. **Streptomyces flavochromogenes** (Krainsky) *comb. nov.* (*Actinomyces flavochromogenes* Krainsky, Cent. f. Bakt., II Abt., *41*, 1914, 662.) From Latin *flavus*, yellow and Greek, producing color.

Conidia oval, 1.7 microns.

Gelatin colonies: Yellowish colonies.

Gelatin stab: Slight liquefaction.

Plain agar: Aerial mycelium formed late, at first white, later gray. Gray soluble pigment formed.

Ca-malate agar: Colonies yellow with white aerial mycelium forming late.

Glucose agar: Brown soluble pigment formed.

Starch agar: Yellow colonies, with white aerial mycelium.

Glucose broth: Fine flakes, with small spherical colonies adherent to glass. Medium colored brown.

Potato: Yellow colonies, with white aerial mycelium.

Nitrites produced from nitrates.

Weakly diastatic. Esculin acted upon.

Slow growth on cellulose.

Tyrosinase formed.

Aerobic.

Optimum temperature 35°C.

Habitat: Soil.

19. **Streptomyces antibioticus** (Waksman and Woodruff) *comb. nov.* (*Actinomyces antibioticus* Waksman and Woodruff, Jour. Bact., *42*, 1941, 232 and 246.) From Greek, antibiotic.

Spore-bearing hyphae produced in the form of straight aerial hyphae. The conidiophores are arranged in clusters; no spirals formed. The conidia are nearly spherical to somewhat elliptical.

Gelatin: Dark brown growth on surface, with patches of gray aerial mycellium. Dark pigment produced, which gradually diffuses into the unliquefied part of the gelatin. Liquefaction at first very slow, later becoming rapid.

Czapek's agar: Thin, whitish growth. Thin, gray aerial mycelium.

Peptone media: Production of dark pigment at early stage of growth is very characteristic. Growth brownish, thin, with a yellowish-gray to yellowish-green aerial mycelium.

Potato plug: Folded, brown-colored growth, with a thin black ring on plug, fading into a bluish tinge. No aerial mycelium.

Carrot plug: Cream-colored to faint brownish growth. No aerial mycelium. No pigment.

Litmus milk: Thick, brownish ring on surface of milk. Mouse-gray aerial mycelium with greenish tinge; growth becomes brown, especially in drier portions adhering to glass. No reaction change, no coagulation of milk, no clearing; whitish sediment at bottom of tube. Old cultures: Heavy growth ring on surface of milk, heavy precipitation on bottom; liquid brownish to black in upper portion.

Odor: Very characteristic soil odor.

Antagonistic properties: Has a marked antagonistic effect on Gram-positive and Gram-negative bacteria, much more on the former than on the latter, as well as on actinomycetes. It is also active against fungi, which vary in degree of sensitivity. Produces a specific bacteriostatic and bactericidal substance known as actinomycin (Waksman and Woodruff, Jour. Bact., *40*, 1940, 581).

Source: Isolated from soil on *Escherichia coli*-washed-agar plate, using living cells of *E. coli* as the only source of available nutrients.

Habitat: Soil.

20. **Streptomyces viridochromogenes** (Krainsky) *comb. nov.* (*Actinomyces viridochromogenes* Krainsky, Cent. f. Bakt., II Abt., *41*, 1914, 662; Waksman and Curtis, Soil Science, *1*, 1916, 114.) From Latin, green and Greek, producing color.

Filaments with numerous open spirals, 3 to 5 microns in diameter, occurring as side branches and terminal conidia, short ovals or spheres, 1.25 to 1.5 microns.

Gelatin stab: Cream-colored surface growth, becoming greenish. Slow liquefaction.

Synthetic agar: Spreading growth, cream-colored with dark center, becoming dark green; reverse yellowish to light cadmium. Aerial mycelium abundant, spreading, white, becoming light green.

Starch agar: Circular, spreading, yellowish colonies.

Glucose agar: Abundant, spreading, wrinkled, gray growth, becoming black.

Plain agar: Abundant, restricted, gray growth, with greenish tinge.

Glucose broth: Dense, solid ring, brownish, becoming dark green.

Litmus milk: Dark brown surface growth; coagulated; peptonized, with faintly alkaline reaction.

Potato: Abundant, gray-brown growth.

Nitrites produced from nitrates.

Soluble brown pigment formed.

Starch is hydrolyzed.

Aerobic.

Optimum temperature 37°C.

Habitat: Soil.

21. **Streptomyces purpeochromogenus** (Waksman and Curtis) *comb. nov.* (*Actinomyces purpeochromogenus* Waksman and Curtis, Soil Science, *1*, 1916, 113.) From Latin, purple and Greek, producing color.

Branching mycelium and hyphae with few imperfect spirals. Conidia spherical, 0.75 to 1.0 micron in diameter.

Gelatin stab: Slow, brownish surface growth. Slow liquefaction.

Synthetic agar: Slow, restricted, smooth, gray growth, becoming brown with purplish tinge; center raised. Margin yellow.

Starch agar: Small, dark brown colonies.

Glucose agar: Abundant, restricted, gray growth, becoming brown to dark brown.

Plain agar: Gray to brownish growth, becoming dark brown, almost black.

Glucose broth: Slight, flaky sediment.

Litmus milk: Dark-brown ring; coagulated; slowly peptonized, with faintly alkaline reaction.

Potato: Restricted, orange to orange-red growth.

Nitrites not produced from nitrates.

Soluble dark brown pigment formed.

Starch shows slight hydrolysis.

Aerobic.

Optimum temperature 25°C.

Source: Isolated once from California adobe soil.

Habitat: Soil.

22. **Streptomyces phaeochromogenus** (Conn) *comb. nov.* (*Actinomyces pheochromogenus* (sic) Conn, N. Y. State Agr. Exp. Sta. Tech. Bull. No. 60, 1917, 16.) From Greek, producing a brown color.

Branching filaments and hyphae, spirals narrow, open, elongated, sinistrorse.

Gelatin stab: Abundant, spreading, cream-colored surface growth, becoming brown. Slow liquefaction.

Synthetic agar: Colorless growth, becoming brown to almost black. Aerial mycelium abundant, white with brownish shade.

Starch agar: Spreading, brownish growth, becoming brown.

Glucose agar: Restricted, much folded, brown growth.

Plain agar: Thin, cream-colored growth, becoming gray.

Glucose broth: Dense, wrinkled pellicle.

Litmus milk: Dark, almost black ring; coagulated, with slow peptonization, faintly alkaline reaction.

Potato: Brown to almost black growth.

Nitrites produced from nitrates.

Soluble brown pigment formed.

Starch is hydrolyzed.

Aerobic.

Optimum temperature 25°C.

Source: Isolated from soil.

Habitat: Soil.

23. **Streptomyces aureus** (Waksman and Curtis) *comb. nov.* (*Actinomyces aureus* Waksman and Curtis, Soil Science, *1*, 1916, 124; not *Actinomyces aurea* Ford, Textb. of Bact., 1927, 220.) From Latin *aureus*, golden.

Mycelium shows numerous spirals. Conidia spherical to oval, 0.6 to 1.0 by 0.8 to 1.4 microns.

Gelatin stab: Fair, cream-colored surface growth, becoming brown, spreading. Liquefied.

Synthetic agar: Thin, spreading, color-

less growth. Aerial mycelium thin, gray, powdery, becoming cinnamon drab.

Starch agar: Thin, transparent, spreading growth.

Glucose agar: Spreading, light orange growth, raised center, hyaline margin.

Plain agar: Restricted, gray growth.

Glucose broth: Thin, brownish ring; flaky sediment.

Litmus milk: Black ring. No coagulation. Peptonization doubtful.

Potato: Abundant, wrinkled, brown growth, becoming black.

Nitrites produced from nitrates.

Soluble brown pigment formed.

Starch is hydrolyzed.

Aerobic.

Optimum temperature 25°C.

Source: Isolated many times from a variety of soils.

Habitat: Soil.

24. **Streptomyces erythrochromogenes** (Krainsky) *comb. nov.* (*Actinomyces erythrochromogenes* Krainsky, Cent. f. Bakt., II Abt., *41*, 1914, 662; Waksman and Curtis, Soil Science, *1*, 1916, 112.) From Greek, producing a red color.

Conidia oval, about 2.0 microns long.

Gelatin colonies: Slow growth.

Gelatin stab: Liquefied. A soluble brown pigment formed.

Plain agar: Brown soluble pigment. White aerial mycelium.

Ca-malate agar: Colonies circular, with grayish-white margined aerial mycelium.

Glucose agar: Red pigment formed.

Starch agar: A soluble rose pigment on old cultures.

Glucose broth: Abundant growth. Floating colonies, later a pellicle is formed. Brown soluble pigment.

Potato: Gray aerial mycelium. Medium colored black.

Nitrates show slight reduction.

Weakly diastatic.

No proteolytic enzyme formed.

No growth in cellulose.

Aerobic.

Optimum temperature 30°C.

Source: Soil and roots of *Alnus* (alder).

Habitat: Soil.

25. **Streptomyces lavendulae** (Waksman and Curtis) *comb. nov.* (*Actinomyces lavendulae* Waksman and Curtis, Soil Science, *1*, 1916, 126.) From M. L., lavender.

Hyphae coarse, branching. Spirals close, 5 to 8 microns in diameter. Conidia oval, 1.0 to 1.2 by 1.6 to 2.0 microns.

Gelatin stab: Creamy to brownish surface growth. Liquefied.

Synthetic agar: Thin, spreading, colorless growth. Aerial mycelium cottony, white, becoming vinous-lavender.

Starch agar: Restricted, glistening, transparent growth.

Plain agar: Gray, wrinkled growth.

Glucose broth: Abundant, flaky sediment.

Litmus milk: Cream-colored ring. No coagulation; peptonized, with strong alkaline reaction.

Potato: Thin, wrinkled, cream-colored to yellowish growth.

Nitrites produced from nitrates.

Soluble brown pigment formed.

Starch is hydrolyzed.

Aerobic.

Optimum temperature 37°C.

Certain strains of this organism produce antibiotics. One such antibiotic, designated as streptothricin, is active both in vitro and in vivo against various Gram-positive and Gram-negative bacteria, fungi and actinomycetes (Waksman and Woodruff, Proc. Soc. Exp. Biol. Med., *49*, 1942, 207; Waksman, Jour. Bact., *46*, 1943, 299).

Source: Isolated once from orchard soil.

Habitat: Soil.

26. **Streptomyces reticuli** (Waksman and Curtis) *comb. nov.* (*Actinomyces reticuli* Waksman and Curtis, Soil Science, *1*, 1916, 118.) From Latin *reticulum*, a small net.

Mycelium in whorls; spirals formed on

glucose agar are sinistrorse. Conidia spherical, 1.0 to 1.4 microns in diameter.

Gelatin stab: Liquefied with small, brown flakes.

Synthetic agar: Colorless growth, with yellowish tinge, becoming brownish, spreading. Aerial mycelium thin, white, cottony.

Starch agar: Brownish-gray growth.

Glucose agar: Restricted, brownish growth, center raised.

Plain agar: Gray, wrinkled growth, becoming brownish.

Glucose broth: Sediment consisting of large colonies.

Litmus milk: Reaction unchanged; coagulated; peptonized.

Potato: Gray growth, with black center.

Nitrites produced from nitrates.

Dark brown pigment formed.

Starch is hydrolyzed.

Aerobic.

Optimum temperature 25°C.

Source: From upland and adobe soils in California.

Habitat: Soil.

27. **Streptomyces rubrireticuli** *nom. nov.* (*Actinomyces reticulus-ruber* Waksman, Soil Science, *8*, 1919, 146; *Actinomyces reticulus* Bergey et al., Manual, 2nd ed., 1925, 373.) From Latin *ruber*, red and *reticulum*, a small net.

Branching filaments with both primary and secondary whorl formation. Spirals formed on glucose agar. Conidia oval-shaped.

Gelatin stab: Surface growth yellowish-red to dragon-pink. Liquefied.

Synthetic agar: Abundant, spreading growth, usually pink. Aerial mycelium thin, rose to pink.

Starch agar: White growth with red tinge.

Glucose agar: Abundant, spreading, rose-red, entire growth.

Plain agar: Red growth, with yellowish margin, becoming red.

Glucose broth: Thin, flaky sediment.

Litmus milk: Abundant, red pellicle; coagulated; peptonized. Reaction unchanged.

Potato: Cream-colored growth, later pink to dark red.

Nitrites produced from nitrates.

Soluble dark brown pigment formed.

Starch is hydrolyzed.

Aerobic.

Certain strains of this organism produce an antibiotic.

Source: Isolated from New Jersey orchard and California upland soils.

Optimum temperature 37°C.

Habitat: Soil.

28. **Streptomyces flavus** (Krainsky) *comb. nov.* (*Actinomyces flavus* Krainsky, Cent. f. Bakt., II Abt., *41*, 1914, 662; Waksman and Curtis, Soil Science, *1*, 1916, 118; not *Actinomyces flavus* Sanfelice, Cent. f. Bakt., I Abt., Orig., *36*, 1905, 359.) From Latin *flavus*, yellow.

Coarse filaments with branching hyphae. Conidia formed by budding and breaking up of hyphae into oval forms.

Gelatin stab: Small, yellowish masses on surface of liquefied medium.

Synthetic agar: Circular, yellow or sulfur-yellow colonies. Aerial mycelium straw-yellow.

Starch agar: Spreading, cream-colored growth, with pink tinge.

Glucose agar: Restricted, raised, folded, sulfur-yellow growth, center shading to brown.

Plain agar: Gray, spreading, folded growth.

Glucose broth: Small, white colonies in bottom of tube.

Litmus milk: Coagulated; peptonized, becoming distinctly alkaline.

Potato: Elevated, much wrinkled, greenish-olive growth.

Traces of nitrite formed.

Soluble brown pigment formed.

Starch is hydrolyzed.

Aerobic.

Optimum temperature 25°C.
Habitat: Soil.

29. **Streptomyces ruber** (Krainsky) *comb. nov.* (*Actinomyces ruber* Krainsky, Cent. f. Bakt., II Abt., *41*, 1914, 662; Waksman, Soil Science, *8*, 1919, 149; not *Actinomyces ruber* Sanfelice, Cent. f. Bakt., I Abt., Orig., *36*, 1904, 355; *Nocardia krainskii* Chalmers and Christopherson, Ann. Trop. Med. and Parasit., *10*, 1916, 268.) From Latin *ruber*, red.

Straight, branching mycelium, radiating. A few spirals may be formed.

Gelatin stab: Liquefaction, with yellow flakes.

Synthetic agar: Abundant, spreading, red growth. Aerial mycelium abundant, cottony, chrome-orange.

Starch agar: Abundant, spreading, red growth.

Glucose agar: Restricted, abundant, entire, coral-red growth.

Plain agar: Restricted, elevated, wrinkled, olive-green growth.

Glucose broth: Red ring, with spongy colonies on the surface.

Litmus milk: Dark ring with red tinge; coagulated; peptonized, with alkaline reaction.

Potato: Elevated, wrinkled, greenish growth.

Nitrites produced from nitrates.

Soluble brown pigment formed.

Starch is hydrolyzed.

Aerobic.

Optimum temperature 37°C.

Habitat: Soil.

30. **Streptomyces citreus** (Krainsky) *comb. nov.* (*Actinomyces citreus* Krainsky, Cent. f. Bakt., II Abt., *41*, 1914, 662; Waksman and Curtis, Soil Science, *1*, 1916, 99; not *Actinomyces citreus* Gasperini, Cent. f. Bakt., *15*, 1894, 684.) From M. L. *citreus*, lemon-yellow.

Filaments with long, narrow open spirals. Conidia spherical to oval, 1.2 to 1.5 by 1.2 to 1.8 microns.

Gelatin stab: Yellowish, restricted surface growth. Liquefaction in 35 days.

Synthetic agar: Abundant, spreading, raised, wrinkled, citron-yellow growth. Aerial mycelium covering surface; citron-yellow.

Starch agar: Abundant, yellowish-green growth.

Glucose agar: Extensive, glossy, olive-yellow, entire growth; center elevated.

Plain agar: Restricted, cream-colored growth.

Glucose broth: Thin, wide, yellow ring; flaky sediment.

Litmus milk: Cream-colored surface growth; coagulated; peptonized, becoming alkaline.

Potato: Yellowish growth, aerial mycelium white.

Trace of nitrite production from nitrate.

The pigment formed is not soluble.

Starch hydrolyzed.

Aerobic.

Optimum temperature 37°C.

Habitat: Soil.

31. **Streptomyces fulvissimus** (Jensen) *comb. nov.* (*Actinomyces fulvissimus* Jensen, Soil Science, *30*, 1930, 66.) From Latin *fulvissimus*, very yellow.

Vegetative mycelium without any special characteristics; aerial mycelium of short, straight, often trifurcated hyphae, 1.0 to 1.2 microns broad; no spiral formation; branches of hyphae break up into conidia, 1.0 to 1.2 by 1.2 to 1.5 microns.

Gelatin: Vegetative mycelium narrow, smooth, yellowish-brown to red-brown; no aerial mycelium; no pigment; gelatin completely liquefied in 10 to 12 days.

Nutrient agar: Good growth; vegetative mycelium raised, finely wrinkled, deep red-brown; no aerial mycelium; brownish-yellow pigment.

Czapek's agar: Good growth (one strain very scant), vegetative mycelium flat, narrow, first light golden, later deep orange to red-brown; aerial mycelium scant, sometimes almost absent, first

white, later light grayish-brown; pigment very characteristic, bright golden to orange.

Glycerol agar: Good growth; vegetative mycelium narrow, raised, smooth, golden to dark bronze; aerial mycelium scant, in patches, white to light cinnamon-brown; pigment intensely golden to orange.

Starch-casein agar: Good growth; vegetative mycelium spreading, folded, yellowish-brown; aerial mycelium abundant, smooth, lead-gray; pigment dull yellow to orange.

Potato: Good growth; vegetative mycelium raised, much wrinkled, rust-brown; aerial mycelium absent or traces of white; pigment gray to faint lemon-yellow.

Loeffler's blood serum: Vegetative mycelium red-brown; no aerial mycelium; yellowish pigment; no liquefaction.

Distinctive characters: The characteristic golden pigment is formed in nearly all media in which the organism grows, but becomes most typical and attains its greatest brightness in synthetic agar media; it has indicator properties, turning red in strongly acid solutions. The species is easily recognized on agar plates by its bronze-colored colonies, surrounded by haloes of bright yellow pigment.

Source: Very common in Danish soils.

Habitat: Soil.

32. **Streptomyces gougeroti** (Duché) *comb. nov.* (*Actinomyces gougeroti* Duché, Encyclopédie Mycologique, Paris, *6*, 1934, 272.) Named for Prof. Gougerot, from whom the culture was obtained.

Gelatin: Cream-colored colonies developing slowly with faint aerial mycelium; no pigment; liquefaction.

Plain agar: Cream-colored growth forming concentric ring with age, with brownish reverse; faint yellowish soluble pigment.

Synthetic agar: Slow growth as punctiform colonies; cream-colored with smooth edge; no aerial mycelium; no soluble pigment.

Peptone broth: Cream-colored ring on surface of medium with flakes throughout the medium; no soluble pigment.

Synthetic solution: Submerged mycelium in the form of flakes, later forming a surface pellicle; filaments of aerial mycelium 1 micron in diameter, with numerous conidia; cream-colored growth; no soluble pigment.

Tyrosine medium: Good growth with white aerial mycelium; no soluble pigment.

Litmus milk: Growth in the form of colonies which remain separated from one another; also flakes in the bottom of the tube with bluish tinge on reverse of growth; milk turns blue in 10 to 12 days.

Coagulated serum: Cream-colored growth covered with white aerial mycelium; rapid liquefaction of serum.

Potato: Slow growth of a greenish tinge; aerial mycelium; no black pigment.

Distinctive character: Intermediate between *Streptomyces albus* with its abundant aerial mycelium and *Actinomyces almquisti* with its very scanty aerial mycelium.

Source: Culture obtained from the collection of Prof. Gougerot.

33. **Streptomyces violaceoniger** (Waksman and Curtis) *comb. nov.* (*Actinomyces violaceus-niger* Waksman and Curtis, Soil Science, *1*, 1916, 111.) From Latin *violaceus*, violet and *niger*, black.

Gelatin: Gray growth, with no production of aerial mycelium. Gelatin around colony rapidly liquefied, but without any change in color.

Czapek's agar: Colony at first dark gray, turning almost black, 2 to 4 mm in diameter. Surface glossy, much folded with a very thin gray margin. A white to gray aerial mycelium is produced after the colony has well developed. A bluish-black pigment is produced at a later stage of its growth. The pigment slowly dissolves in the medium, turning almost

black. Odor fairly strong. Microscopically two types of mycelium are found: the thin, branching filaments of the substratum, and the thick filaments of the aerial mycelium. The aerial mycelium fragments not very rapidly, producing a few conidia, spherical and oval, 1.2 to 1.5 by 1.2 to 2.3 microns. These often occur in chains.

Czapek's solution: Colonies large, 2 to 3 mm in diameter, appearing at the bottom and surface of the solution, but none throughout the medium. Colonies bluish in color, with a regular margin. Medium not colored.

Potato plug: Growth at first very slight, but after 48 hours develops into a yellowish-gray continuous thick smear which later turns brown, with a white aerial mycelium covering the growth. Medium not colored.

Source: Isolated once from the upland California soil.

Habitat: Soil.

34. **Streptomyces griseus** (Krainsky) *comb. nov.* (*Actinomyces griseus* Krainsky, Cent. f. Bakt., II Abt., *41*, 1914, 662.) From M. L. *griseus*, gray.

Branching filaments; a few spirals have been observed. Conidia rod-shaped to short cylindrical, 0.8 by 0.8 to 1.7 microns. Aerial mycelium greenish-gray.

Gelatin stab: Greenish-yellow or cream-colored surface growth with brownish tinge. Rapid liquefaction.

Synthetic agar: Thin, colorless, spreading growth, becoming olive buff. Aerial mycelium thick, powdery, water-green.

Starch agar: Thin, spreading, transparent growth.

Glucose agar: Growth elevated in center, radiate, cream-colored to orange, erose margin.

Plain agar: Abundant, cream-colored, almost transparent growth.

Glucose broth: Abundant, yellowish pellicle with greenish tinge, much folded.

Litmus milk: Cream-colored ring; coagulated with rapid peptonization, becoming alkaline.

Potato: Yellowish, wrinkled growth.

Nitrites produced from nitrates.

The pigment formed is not soluble.

Starch is hydrolyzed.

Aerobic.

Optimum temperature 37°C.

Different strains of this organism produce different antibiotics. One of these, streptomycin, was isolated in crystalline form. It is active against a large number of bacteria and actinomycetes, but not against fungi and viruses. It is not very toxic to animals, and has found extensive application in the treatment of various diseases, mostly caused by Gram-negative bacteria and certain forms of tuberculosis.

Source: Garden soil.

Habitat: Soil.

35. **Streptomyces griseoflavus** (Krainsky) *comb. nov.* (*Actinomyces griseoflavus* Krainsky, Cent. f. Bakt., II Abt., *41*, 1914, 662.) From M. L. *griseus*, gray and Latin *flavus*, yellow.

Conidia oval, 1.2 microns.

Gelatin colonies: Yellowish. Concentric rings.

Gelatin stab: Rapidly liquefied.

Plain agar: Colonies yellowish, with white aerial mycelium.

Ca-malate agar: Large colonies covered with yellow to greenish-gray aerial mycelium.

Glucose agar: White aerial mycelium is slowly formed.

Starch agar: White aerial mycelium.

Glucose broth: Flaky growth.

Litmus milk: Peptonized.

Potato: Yellowish growth, aerial mycelium gray.

Nitrites produced from nitrates.

Weakly diastatic. Acts on esculin.

Grows well on cellulose.

Aerobic.

Optimum temperature 35°C.

Habitat: Soil.

36. **Streptomyces albidoflavus** (Rossi Doria) *comb. nov.* (*Streptotrix* (sic) *albido-flava* Rossi Doria, Ann. d. Ist. d'Ig. sper. d. Univ. di Roma, *1*, 1891, 407; *Actinomyces albido-flavus* Gasperini, *ibid.*, *2*, 1892, 222; *Streptothrix albido* Chester, Man. Determ. Bact., 1901, 365; *Cladothrix albido-flava* Macé, Traité Pratique de Bact., 4th ed., 1901, 1097; *Nocardia albida* Chalmers and Christopherson, Ann. Trop. Med. and Parasit., *10*, 1916, 271.) From Latin *albidus*, white and *flavus*, yellow.

Description from Duché, Encyclopédie Mycologique, Paris, *6*, 1934, 294.

Gelatin: Punctiform colonies with white aerial mycelium on surface of liquid; no soluble pigment; rapid liquefaction.

Synthetic asparagine agar: Growth becomes rapidly covered with white aerial mycelium, later becoming whitish-yellow; brown on reverse side; yellowish soluble pigment.

Peptone agar: Cream-colored growth covered with fine white aerial mycelium; yellow soluble pigment.

Tyrosine agar: Fine growth with orange-yellow on reverse side; medium becomes colored yellowish to yellowish-rose.

Synthetic asparagine solution: Long branching filaments, 0.6 micron in diameter. Thicker aerial mycelium producing irregular spores; flaky growth dropping to bottom of tube. Surface growth becomes covered with yellowish-white aerial mycelium; brownish on reverse side; soluble pigment yellowish.

Peptone solution: Rapid, much folded growth, partly covered with white mycelium on surface of medium; soluble yellow-ochre pigment.

Milk: Rapid growth becoming covered with whitish aerial mycelium; never fully covering the surface; no coagulation; peptonization begins slowly and is completed in 13 days, liquid becoming colored yellowish-orange.

Coagulated serum: Cream-colored growth of surface becoming covered with white aerial mycelium; rapid liquefaction of serum.

Starch medium: Cream-colored growth rapidly colored with yellow aerial mycelium; after 20 days growth becomes much folded; greenish on reverse side; slightly amber color in medium.

This strain is closely related to *Streptomyces albus*. Develops poorly on Czapek's medium without asparagine.

Source: From dust.

37. **Streptomyces poolensis** (Taubenhaus) *comb. nov.* (*Actinomyces poolensis* Taubenhaus, Jour. Agr. Res., *13*, 1918, 446.) Named for Prof. R. F. Poole, plant pathologist.

Description from Waksman, Soil Sci., *8*, 1919, 140.

Fine, branching mycelium; spirals usually not seen. Conidia oval to elliptical.

Gelatin stab: Liquefied, with small, brownish flakes in fluid.

Synthetic agar: Thin, colorless, spreading growth. Aerial mycelium white to gray.

Starch agar: Restricted, cream-colored growth.

Glucose agar: Growth abundant, light brown, glossy, raised center, entire.

Plain agar: Yellowish, translucent growth.

Glucose broth: Thin, brownish ring.

Litmus milk: Brownish ring; coagulated; peptonized, with strongly alkaline reaction.

Potato: Thin, reddish-brown; medium becoming purplish.

Nitrites produced from nitrates.

Faint trace of soluble brown pigment.

Starch not hydrolyzed.

Aerobic.

Optimum temperature 37°C.

Source: Associated with disease of sweet potato.

38. **Streptomyces olivaceus** (Waksman) *comb. nov.* (Actinomyces 206, Waksman, Soil Science, 7, 1919, 117; *Actinomyces olivaceus* Waksman, in Manual, 1st ed., 1923, 354.) From Latin, olive-colored.

Small clumps, with straight and branching hyphae. No spirals on most media. Conidia spherical and oval, 0.9 to 1.1 by 0.9 to 2.0 microns.

Gelatin stab: Liquefied with cream-colored, flaky, yellow sediment.

Synthetic agar: Growth abundant, spreading, developing deep into medium, yellow to olive-ochre, reverse yellow to almost black. Aerial mycelium mouse-gray to light drab.

Starch agar: Thin, yellowish-green, spreading growth.

Glucose agar: Growth abundant, restricted, entire, center raised.

Plain agar: White, glistening growth.

Glucose broth: Sulfur-yellow ring.

Litmus milk: Faint, pinkish growth; coagulated; peptonized, becoming alkaline.

Potato: Growth abundant, much wrinkled, elevated, gray, turning sulfur-yellow on edge.

Nitrites produced from nitrates.

The pigment formed is not soluble.

Starch is hydrolyzed.

Aerobic.

Optimum temperature 25°C.

Habitat: Soil.

39. **Streptomyces lieskei** (Duché) *comb. nov.* (*Actinomyces lieskei* Duché, Encyclopédie Mycologique, Paris, *6*, 1934, 289.) Named for Prof. Lieske of Leipzig.

Gelatin: Cream-colored growth becoming covered with white aerial mycelium; no soluble pigment. Rapid liquefaction.

Plain agar: Cream-colored growth becoming covered with white aerial mycelium; yellowish soluble pigment.

Synthetic agar: Cream-colored growth with delayed white aerial mycelium growing from the edge toward the center; mycelium later yellowish. Reverse of growth yellowish to green. Dirty yellow to yellow-green soluble pigment.

Synthetic solution: Long branching filaments 0.7 micron in diameter. Yellowish-white aerial mycelium does not readily produce spores; flakes drop to the bottom of the tube.

Peptone solution: Cream-colored colonies on surface with flakes in the liquid dropping to the bottom of the tube. Liquid becomes yellowish in color.

Tyrosine medium: Rapid growth on surface with whitish-yellow aerial mycelium; yellowish to orange-yellow soluble pigment.

Milk: Cream-colored growth; colorless on reverse side; no aerial mycelium. Peptonization without coagulation. After 20 days the whole milk becomes a clear yellowish liquid.

Coagulated serum: Clear-colored growth. Rapid liquefaction.

Culture related to *Streptomyces alboflavus* and *Streptomyces albidoflavus*.

40. **Streptomyces microflavus** (Krainsky) *comb. nov.* (*Actinomyces microflavus* Krainsky, Cent. f. Bakt., II Abt., *41*, 1914, 662; *Micromonospora microflava* Duché, Encyclopédie Mycologique, Paris, *6*, 1934, 29.) From Greek *micrus*, small, and Latin *flavus*, yellow.

Conidia large, spherical to rod-shaped, often in pairs or chains, 2.0 by 2.0 to 5.0 microns.

Gelatin colonies: Small, yellow.

Gelatin stab: Liquefied.

Plain agar: Yellow colonies, with rose-yellow aerial mycelium in 3 to 4 weeks.

Ca-malate agar: Minute yellow colonies. No aerial mycelium.

Glucose agar: A rose-yellow aerial mycelium develops in about 12 days.

Starch agar: Same as on glucose agar.

Glucose broth: Small spherical colonies in depth.

Litmus milk: Peptonized.

Potato: Yellow growth. No aerial mycelium.

Nitrites produced from nitrates.

Strongly diastatic.
Scant growth on cellulose.
Starch is hydrolyzed.
Aerobic.
Optimum temperature 25°C.
Habitat: Soil.

41. **Streptomyces cacaoi** (Waksman) *comb. nov.* (*Actinomyces cacaoi* Waksman, in Bunting, Ann. Appl. Biol., *19*, 1932, 515.) Named for the chocolate tree (*Theobroma cacao*).

Long aerial mycelium with considerable spiral formation; the spirals are long and open, not compact.

Gelatin: Flocculent growth. No aerial mycelium. Rapid liquefaction. No pigment production.

Nutrient agar: Brown-colored growth covered with tiny patches of ivory-colored aerial mycelium.

Glucose agar: Thin yellowish growth, later turning reddish-brown; no soluble pigment; light gray to mouse-gray mycelium, with white edge. Typical odor of streptomyces.

Czapek's agar: Same as on glucose agar.

Potato: Abundant brownish growth with white to mouse-gray aerial mycelium.

Biochemical characteristics: Strong proteolytic enzymes acting on casein and gelatin; strong diastatic action, no sugar or dextrin left in 1 per cent starch solution after a few days. Limited reduction of nitrate.

Source: Three strains isolated from cacao beans in Nigeria. There were slight differences among the three strains; the above description is of Strain I.

42. **Streptomyces novaecaesareae** *nom. nov.* (*Actinomyces violaceus-caesari* Waksman and Curtis, Soil Science, *1*, 1916, 111.) From *Nova Caesarea*, Latin name for the State of New Jersey.

Filaments with both straight and spiral aerial hyphae; spirals dextrorse. Conidia oval to elongate.

Gelatin stab: Small, cream-colored surface colonies with slow liquefaction.

Synthetic agar: Growth gray, becoming bluish, glossy, much wrinkled. Aerial mycelium appears late; white.

Starch agar: Restricted, circular, blueish-violet colonies.

Glucose agar: Restricted, gray growth, becoming red.

Plain agar: Thin, cream-colored growth.

Glucose broth: Fine, colorless, flaky sediment.

Litmus milk: Gray ring; coagulated; slow peptonization, becoming faintly alkaline.

Potato: Growth cream-colored, wrinkled, turning yellowish.

Nitrites produced from nitrates.
Soluble purple pigment formed.
Starch is hydrolyzed.
Aerobic.
Optimum temperature 37°C.

Source: Isolated once from upland California soil.

Habitat: Soil.

43. **Streptomyces exfoliatus** (Waksman and Curtis) *comb. nov.* (*Actinomyces exfoliatus* Waksman and Curtis, Soil Science, *1*, 1916, 116.) From Latin, stripped of foliage.

Slightly wavy filaments with tendency to form spirals. Conidia oval, 1.0 to 1.5 by 1.2 to 1.8 microns.

Gelatin stab: Cream-colored surface growth. Liquefied.

Synthetic agar: Growth colorless, becoming brown, smooth, glossy. Aerial mycelium in white patches over surface.

Starch agar: Restricted, gray growth, becoming brown.

Plain agar: Grows only in depth of medium.

Glucose broth: Small, grayish colonies in depth.

Litmus milk: Cream-colored ring, soft coagulum in 12 days; slow peptonization, becoming strongly alkaline.

Potato: Growth somewhat wrinkled, gray, becoming brown.

Nitrites produced from nitrates.
Brown, soluble pigment formed.

Starch is hydrolyzed.

Aerobic.

Optimum temperature 37°C.

Source: Isolated several times from adobe and upland soils in California.

Habitat: Soil.

44. **Streptomyces gelaticus** (Waksman) *comb. nov.* (Actinomyces 104, Waksman, Soil Science, *8*, 1919, 165; *Actinomyces gelaticus* Waksman, in Manual, 1st ed., 1923, 356.) From M. L. *gelaticus*, gelatinous.

Branching mycelium with open spirals.

Gelatin stab: Liquefied with cream-colored flaky sediment.

Synthetic agar: Growth colorless, spreading, chiefly deep into the medium. Aerial mycelium thin, white, turning grayish.

Starch agar: Thin, spreading, cream-colored growth.

Glucose agar: Abundant, spreading, white growth.

Plain agar: Wrinkled, cream-colored growth only on the surface.

Glucose broth: Thin, cream-colored pellicle; slight flaky sediment.

Litmus milk: Pinkish ring; coagulated; peptonized with distinctly alkaline reaction.

Potato: Growth abundant, much wrinkled, greenish, becoming black with yellowish margin.

Nitrates show slight reduction to nitrites.

Soluble brown pigment formed.

Starch is hydrolyzed.

Aerobic.

Optimum temperature 25°C.

Habitat: Soil.

45. **Streptomyces rutgersensis** (Waksman and Curtis) *comb. nov.* (*Actinomyces rutgersensis* Waksman and Curtis, Soil Science, *1*, 1916, 123.) Named for Rutgers University, New Brunswick, New Jersey.

Branching filaments with abundant open and closed spirals; hyphae fine, long, branching. Conidia spherical and oval, 1.0 to 1.2 microns, with tendency to bipolar staining.

Gelatin stab: Cream-colored, spreading surface growth. Liquefied.

Synthetic agar: Growth thin, colorless, spreading, becoming brownish to almost black. Aerial mycelium thin, white, becoming dull-gray.

Starch agar: Gray, spreading growth.

Glucose agar: Abundant, brown mycelium, becoming black with cream-colored margin.

Plain agar: Thin, wrinkled, cream-colored growth.

Litmus milk: Cream-colored ring; coagulated; slow peptonization, becoming alkaline.

Potato: Abundant, white-gray, much folded growth.

Nitrites produced from nitrates.

The pigment formed is not soluble.

Starch is hydrolyzed.

Aerobic.

Optimum temperature 37°C.

Source: Isolated many times from a variety of soils.

Habitat: Common in soil.

46. **Streptomyces lipmanii** (Waksman and Curtis) *comb. nov.* (*Actinomyces lipmanii* Waksman and Curtis, Soil Science, *1*, 1916, 123.) Named for Prof. J. G. Lipman, New Jersey Agricultural Experiment Station.

Straight, branching mycelium and hyphae. Conidia oval, 0.8 to 1.1 by 1.0 to 1.5 microns.

Gelatin stab: Liquefied with cream-colored, flaky sediment.

Synthetic agar: Growth abundant, raised, colorless, becoming light brown and wrinkled. Aerial mycelium white, turning gray.

Starch agar: Transparent growth, becoming dark with age.

Glucose agar: Light yellow, irregular, spreading growth.

Plain agar: Yellow, glossy, radiately wrinkled growth.

Glucose broth: White ring, with abundant, colorless flaky sediment.

Litmus milk: Cream-colored ring; coagulated; peptonization with alkaline reaction.

Potato: Abundant, cream-colored, wrinkled growth.

Nitrites produced from nitrates.

The pigment formed is not soluble.

Starch is hydrolyzed.

Aerobic.

Optimum temperature 25°C.

Source: Isolated many times from a variety of soils.

Habitat: Common in soil.

47. **Streptomyces halstedii** (Waksman and Curtis) *comb. nov.* (*Actinomyces halstedii* Waksman and Curtis, Soil Science, *1*, 1916, 124.) Named for a person.

Branching mycelium and hyphae with close spirals. Conidia oval or rod-shaped, 1.0 to 1.2 by 1.2 to 1.8 microns.

Gelatin stab: Liquefied, with small, cream-colored masses in bottom of tube.

Synthetic agar: Growth abundant, heavy, spreading, raised, light, becoming dark, almost black. Aerial mycelium white, turning dull-gray.

Starch agar: Abundant, brownish, glossy growth.

Glucose agar: Growth spreading, colorless, wrinkled, center elevated, edge lichenoid, becoming brown.

Plain agar: Restricted, wrinkled, cream-colored growth.

Glucose broth: Small, colorless colonies in bottom of tube.

Litmus milk: Cream-colored ring; coagulated; peptonized, becoming alkaline.

Potato: Growth abundant, moist, wrinkled, cream-colored with green tinge.

Nitrites produced from nitrates.

The pigment formed is not soluble.

Starch is hydrolyzed.

Optimum temperature 37°C.

Aerobic.

Source: Isolated many times from the deeper soil layers.

Habitat: Common in subsoil.

48. **Streptomyces hygroscopicus** (Jensen) *comb. nov.* (*Actinomyces hygroscopicus* Jensen, Proc. Linn. Soc. New So. Wales, *56*, 1931, 257.) From Greek, hygroscopic.

Hyphae of vegetative mycelium 0.6 to 0.8 micron in diameter. Aerial hyphae long, tangled, branched, 0.8 to 1.0 micron in diameter; spirals numerous, sinistrorse, narrow, usually short, only 1 or 2 turns, closed, typically situated as dense clusters on the main stems of the aerial hyphae. Conidia oval, 0.8 to 1.0 by 1.0 to 1.2 microns.

Gelatin: Slow liquefaction. No pigment produced.

Nutrient agar: Good growth. Vegetative mycelium raised, wrinkled, glossy, cream-colored; later yellowish-gray with yellowish-brown reverse. Occasionally a scant white aerial mycelium.

Sucrose agar: Good to abundant growth. Vegetative mycelium heavy, superficially spreading, folded, glossy surface, white to cream-colored, later sulfur-yellow to yellowish-gray, with golden to light orange reverse. Soluble pigment of the same color. Aerial mycelium scant, thin, white or absent.

Glucose agar: Good growth. Vegetative mycelium superficially spreading, surface granulated, cream-colored to straw-yellow, later dull chrome-yellow to brownish-orange. Aerial mycelium thin, smooth, dusty, white to pale yellowish-gray, after 1 or 2 weeks more or less abundantly interspersed with small, moist, dark violet-gray to brownish patches which gradually spread over the whole surface. Light yellow soluble pigment.

Potato: Fair growth. Vegetative mycelium raised, wrinkled, cream-colored, later yellowish-gray to dull brownish. Aerial mycelium absent or trace of white.

Milk: Completely digested in 3 to 4 weeks at 30°C without any previous coagulation. The reaction becomes faintly acid (pH 6.0 or less).

Nitrates not reduced with sucrose as source of energy.

Sucrose is inverted.

Starch is hydrolyzed.

Cellulose is decomposed readily by some strains.

Distinctive character: In this species, the aerial mycelium (which in other actinomycetes is strikingly hydrophobic) on certain media (glucose or glycerol asparagine agar) becomes moistened and exhibits dark, glistening patches. These patches, when touched with a needle, prove to be a moist, smeary mass of spores. This characteristic feature is not equally distinct in all strains.

Source: Seven strains isolated from soils.

Habitat: Soil.

49. **Streptomyces fradiae** (Waksman and Curtis) *comb. nov.* (*Actinomyces fradii* Waksman and Curtis, Soil Science, *1*, 1916, 125.) From the name of a person.

Straight, branching filaments and hyphae. No spirals. Conidia rod- or oval-shaped, 0.5 by 0.7 to 1.25 microns.

Gelatin stab: Cream-colored to brownish, dense growth on liquid medium.

Synthetic agar: Smooth, spreading, colorless growth. Aerial mycelium thick, cottony mass covering surface, sea-shell pink.

Starch agar: Spreading, colorless growth.

Glucose agar: Growth restricted, glossy, buff-colored, lichenoid margin.

Plain agar: Growth yellowish, becoming orange-yellow, restricted.

Glucose broth: Dense, narrow, orange-colored ring; abundant, flaky, colorless sediment.

Litmus milk: Faint, cream-colored ring; coagulated; peptonized, becoming alkaline.

Potato: Restricted, orange-colored growth.

Nitrites not produced from nitrates.

The pigment formed is not soluble.

Starch is hydrolyzed.

Aerobic.

Optimum temperature 25°C.

Source: Isolated once from adobe soil in California.

Habitat: Soil.

50. **Streptomyces alboflavus** (Waksman and Curtis) *comb. nov.* (*Actinomyces alboflavus* Waksman and Curtis, Soil Science, *1*, 1916, 120.) From Latin *albus*, white and *flavus*, yellow.

Straight, branching mycelium, with very little tendency to form spirals. Very few oval-shaped conidia formed.

Gelatin stab: Abundant, colorless surface growth. Liquefaction occurs in 35 days.

Synthetic agar: Growth glossy, colorless, spreading, becoming yellowish. Aerial mycelium white, powdery, with yellow tinge.

Starch agar: Thin, yellowish, spreading growth.

Glucose agar: Growth restricted, much-folded, creamy with sulfur-yellow surface.

Plain agar: Restricted, cream-colored growth.

Glucose broth: White, cylindrical colonies on surface, later flaky mass in bottom of tube.

Litmus milk: Pinkish ring. No coagulation. Peptonized, becoming alkaline.

Potato: Moist, cream-colored, wrinkled growth.

Nitrites produced from nitrates.

The pigment formed is not soluble.

Starch is hydrolyzed.

Aerobic.

Optimum temperature 37°C.

Source: Isolated once from orchard soil.

Habitat: Soil.

51. **Streptomyces albosporeus** (Krainsky) *comb. nov.* (*Actinomyces albosporeus* Krainsky, Cent. f. Bakt., II Abt., *41*, 1914, 649; *Nocardia albosporea* Chalmers and Christopherson, Ann. Trop. Med. and Parasit., *10*, 1916, 268; Waksman and Curtis, Soil Science, *1*, 1916, 99.) From Latin *albus*, white and Greek *spora*, spore.

Straight, branching filaments with straight, branching hyphae, and occasional spirals. Conidia spherical or oval, 0.8 to 1.2 by 1.0 to 1.8 microns.

Gelatin stab: Growth yellow, changing to red, with hyaline margin. Liquefaction in 35 days.

Synthetic agar: Growth spreading, colorless with pink center, becoming brownish. Aerial mycelium white at first, later covering the surface.

Starch agar: Growth thin, spreading, transparent, with red tinge.

Glucose agar: Growth spreading, red, wrinkled, radiate, entire.

Plain agar: Minute, cream-colored colonies.

Glucose broth: Pinkish ring.

Litmus milk: Scant, pink ring. No coagulation. No peptonization.

Potato: Growth thin, spreading, wrinkled, gray, becoming brown with greenish tinge.

Nitrites produced from nitrates.

The pigment formed is not soluble.

Starch is hydrolyzed.

Aerobic.

Optimum temperature 37°C.

Habitat: Soil.

52. **Streptomyces flocculus** (Duché) *comb. nov.* (*Actinomyces flocculus* Duché, Encyclopédie Mycologique, Paris, *6*, 1934, 300.) From Latin, somewhat woolly, referring to the appearance of the aerial mycelium.

Gelatin: Very limited growth. Slow liquefaction.

Asparagine glucose agar: Weak growth; limited cream-colored colonies hardly raised above the surface of the medium; occasionally abundant growth is produced with white aerial mycelium and colorless on reverse side.

Czapek's agar: Cream-colored growth, later covered with white aerial mycelium; no soluble pigment.

Peptone agar: Cream-colored growth, later covered with white aerial mycelium; no soluble pigment.

Asparagine glucose solution: Branching immersed filaments, 0.8 micron in diameter; aerial mycelium 1.0 by 1.2 microns with numerous conidia; flakes settle to the bottom of the tube.

Peptone solution: Pointed colonies; cream-colored on surface of medium.

Tyrosine medium: Whitish growth without any pigment.

Milk: Rose-colored growth; slow peptonization.

Potato: Punctiform growth covered with white aerial mycelium; faint yellowish pigment.

Coagulated serum: Cream-colored growth; fine white aerial mycelium; slow liquefaction of serum.

Source: Culture obtained from Mr. Malençon, an inspector in Morocco.

53. **Streptomyces melanosporeus** (Krainsky) *comb. nov.* (*Actinomyces melanosporeus* Krainsky, Cent. f. Bakt., II Abt., *41*, 1914, 662; *Nocardia melanosporea* Chalmers and Christopherson, Ann. Trop. Med. and Parasit., *10*, 1916, 268.) From Greek *melas*, black and *spora*, spore.

Conidia almost spherical, 1.2 microns in diameter.

Gelatin colony: Small, reddish colonies.

Gelatin stab: Liquefied.

Ca-malate agar: Colonies red, with black aerial mycelium.

Glucose agar: Same as on Ca-malate agar.

Starch agar: Same as on Ca-malate agar.

Glucose broth: Flaky, orange-red colonies adherent to glass.

Litmus milk: Peptonized.

Potato: Red colonies with black aerial mycelium.

Nitrites produced from nitrates.

Weakly diastatic.

Grows well on cellulose. Cellulose is decomposed.

Aerobic.

Optimum temperature 25°C.
Habitat: Soil.

54. **Streptomyces melanocyclus** (Merker) *comb. nov.* (*Micrococcus melanocyclus* Merker, Cent. f. Bakt., II Abt., *31*, 1911, 589; *Actinomyces melanocyclus* Krainsky, Cent. f. Bakt., II Abt., *41*, 1914, 662; *Nocardia melanocycla* Chalmers and Christopherson, Ann. Trop. Med. and Parasit., *10*, 1916, 268.) From Greek *melas*, black and *cyclus*, circle.

Conidia almost spherical, 0.9 micron in diameter.

Gelatin colonies: Growth poor.

Gelatin stab: Rapid liquefaction.

Ca-malate agar: Colonies small, flat, orange-red. Aerial mycelium black, occurring along the edges.

Glucose broth: Same as on Ca-malate agar.

Starch agar: Same as on Ca-malate agar.

Glucose broth: Colorless, spherical colonies.

Litmus milk: Peptonized.

Nitrites produced from nitrates.

Good diastatic action.

Cellulose is decomposed.

Aerobic.

Optimum temperature 25°C.

Habitat: Soil.

55. **Streptomyces acidophilus** (Jensen) *comb. nov.* (*Actinomyces acidophilus* Jensen, Soil Sci., *25*, 1928, 226.) From Greek, acid-loving.

Vegetative mycelium profusely branched, hyphae 0.6 to 0.8 micron in diameter with homogeneous protoplasm and no visible septa. Aerial mycelium with hyphae 1.0 to 1.2 microns in diameter, somewhat branched, forming either very few or very numerous sinistrorse spirals. Oval conidia 1.0 to 1.2 by 1.2 to 1.5 microns.

Gelatin: After 10 days growth very scant, thin, colorless, semi-transparent. Slow liquefaction.

Nutrient agar: No growth.

Glucose agar: Good growth at 25°C. Substratum mycelium raised, somewhat wrinkled, colorless in young cultures. Aerial mycelium thin, white at first, later gray or yellowish-brown.

Starch agar: Good growth at 25°C. Substratum mycelium flat, smooth, colorless. Aerial mycelium abundant, smooth, white.

Czapek's agar: No growth.

Plain broth: No growth.

Milk: No growth.

Potato: Growth good, raised, folded. No discoloration.

Nitrites not produced from nitrates except a trace in two strains.

Diastatic.

Weakly proteolytic.

Inversion of sucrose: Negative.

Distinctive character: The ability to live in acid media only.

Source: Four strains isolated from three acid humus soils.

Habitat: Acid humus soils.

56. **Streptomyces rubescens** (Jarach) *comb. nov.* (*Streptothrix rubescens* Jarach, Boll. Sez. Ital. Soc. Intern. Microb., *3*, 1931, 43.) From Latin *rubescens*, becoming red.

Gelatin: No liquefaction; limited non-pigmented growth.

Glucose agar: Large number of small round colonies raised in the center and growing together, as well as deep into the medium; of a whitish opalescent color.

Czapek's agar: Poor growth, becoming pigmented salmon-red, edge entire.

Milk agar medium: Rose-coral-colored, thin growth with edge entire.

Broth: Minute flakes, the liquid later becoming reddish-colored.

Milk: No coagulation and no digestion; slight red coloration of milk.

Potato plug: Reddish growth, not extensive; opalescent surface.

Source: From soil.

57. **Streptomyces thermophilus** (Gilbert) *comb. nov.* (*Actinomyces thermophilus* Gilbert, Ztschr. f. Hyg., *47*, 1904, 383; not *Actinomyces thermophilus* Berestnew, Inaug. Diss., Moskow, 1897;

Nocardia thermophila Chalmers and Christopherson, Ann. Trop. Med. and Parasit., *10*, 1916, 271.) From Greek *thermus*, heat and *philus*, loving.

Description from Waksman, Umbreit and Gordon, Soil Sci., *47*, 1939, 49.

Hyphae straight, conidia formed.

Gelatin: Liquefaction.

Czapek's agar: At 28°C, deep colorless growth, thin white aerial mycelium; no soluble pigment.

Starch agar: Yellowish growth with white-gray, powdery aerial mycelium.

Milk: Proteolysis.

Potato plug: Yellowish growth with no aerial mycelium, the plug usually being colored brown.

Starch is hydrolyzed.

No pigment produced on nutrient agar or gelatin.

Temperature relations: Optimum 50°C. Good growth at 28°C. Usually no growth at 60°C. Some strains are incapable of growing at 28°C, whereas others seem to grow well even at 65°C.

Aerobic.

Habitat: Soil, hay, composts.

58. **Streptomyces thermofuscus** (Waksman, Umbreit and Gordon) *comb. nov.* (*Actinomyces thermofuscus* Waksman, Umbreit and Gordon, Soil Sci., *47*, 1939, 49.) From Greek *thermus*, heat and Latin *fuscus*, dark. Presumably derived to mean heat-loving and dark in color.

Hyphae spiral-shaped; conidia produced.

Gelatin: Liquefaction. At 50°C, a grayish ring is produced and soluble pigment is formed. At 28°C, growth with no soluble pigment.

Czapek's agar: Poor growth at 28°C, deep-gray, with but little aerial mycelium. At 50°C, growth dark to violet, with gray to lavender aerial mycelium and soluble brown pigment.

Milk: Proteolysis.

Potato: Abundant, dark-colored growth, no aerial mycelium, or few white patches, dark soluble pigment.

Starch is hydrolyzed.

Temperature relations: Good growth at 50° and 60°C. Will grow at 65°C. Faint growth at 28°C.

Aerobic.

Distinctive characters: This species is distinguished from *Streptomyces thermophilus* by the brown-colored aerial mycelium on synthetic media, spiral-shaped hyphae, and ability to grow readily at 65°C.

Habitat: Soils and composts.

59. **Streptomyces scabies** (Thaxter) *comb. nov.* (*Oospora scabies* Thaxter, Ann. Rept. Conn. Agr. Exp. Sta., 1891, 153; *Actinomyces scabies* Gussow, Science, N. S. *39*, 1914, 431.) From Latin *scabies*, scab.

Wavy or slightly curved mycelium, with long branched aerial hyphae, showing a few spirals. Conidia more or less cylindrical, 0.8 to 1.0 by 1.2 to 1.5 microns.

Gelatin stab: Cream-colored surface growth, becoming brown. Slow liquefaction.

Synthetic agar: Abundant, cream-colored, wrinkled, raised growth. Aerial mycelium white, scarce.

Starch agar: Thin, transparent, spreading growth.

Glucose agar: Restricted, folded, cream-colored, entire growth.

Plain agar: Circular, entire colonies, smooth, becoming raised, lichenoid, wrinkled, white to straw-colored, opalescent to opaque.

Glucose broth: Ring in form of small colonies, settling to the bottom.

Litmus milk: Brown ring with greenish tinge; coagulated; peptonized with alkaline reaction.

Potato: Gray, opalescent growth, becoming black, wrinkled.

Nitrites produced from nitrates.

Brown soluble pigment formed.

Starch is hydrolyzed.

Optimum temperature 37°C.

Aerobic.

The potato scab organism, like other

acid-fast organisms, can be selectively impregnated with carbol-auromin and when exposed to ultraviolet radiation fluoresces bright yellow. This technic confirms Lutman's conclusion that the hyphae are intercellular and grow within the middle lamellae (Richards, Stain Tech., *18*, 1943, 91–94).

Source: Isolated from potato scab lesions.

Habitat: Cause of potato scab; found in soil.

60. **Streptomyces ipomoea** (Person and Martin) *comb. nov.* (*Actinomyces ipomoea* Person and Martin, Phytopath., *30*, 1940, 313.) From M. L. *Ipomoea*, a generic name.

Conidia on glucose-casein agar: Oval to elliptical, 0.9 to 1.3 by 1.3 to 1.8 microns.

Gelatin: After 25 days at 20°C, scanty growth, no aerial mycelium; no soluble pigment; liquefaction.

Synthetic agar: Abundant growth, mostly on surface of medium, moderately wrinkled, olive-yellow.

Nutrient agar: Moderate growth in the form of small, shiny, crinkled colonies both on the surface and imbedded in the medium, silver-colored.

Starch agar: Growth moderate, smooth, deep in medium, ivory-colored. Aerial mycelium white with patches of bluish-green. No soluble pigment. Complete hydrolysis after 12 days.

Milk: Growth in form of ring; hydrolysis, without visible coagulation.

Potato: Growth moderate, light brown, shiny, wrinkled. No aerial mycelium. No soluble pigment.

Nitrites are produced from nitrates.

Starch is hydrolyzed.

No growth on cellulose.

Source: From diseased sweet-potato (*Ipomoea sp.*) tubers and small rootlets from several localities in Louisiana.

61. **Streptomyces fordii** (Erikson) *comb. nov.* (*Actinomyces fordii* Erikson, Med. Res. Counc. Spec. Rept. Ser. 203, 1935, 15 and 36.) Presumably named for the surgeon who first secured the culture.

Mycelium: Filaments of medium length, no spirals or markedly wavy branches. Short, straight, sparse aerial mycelium. Small oval conidia on potato agar and starch agar.

Gelatin: No visible growth, slight softening in 20 days; half-liquefied after 40 days.

Agar: Small, creamy-golden, ring-shaped colonies, and heaped-up patches, becoming golden-brown in color and convoluted.

Glycerol agar: Extensive, golden-brown, convoluted, thin layer.

Serum agar: Golden-brown ring-shaped and coiled smooth colonies; no liquefaction.

Ca-agar: Yellow, scale-like closely adherent colonies; scattered white aerial mycelium.

Blood agar: Innumerable small yellowish ring-shaped colonies; no hemolysis.

Broth: Few flakes at first; later abundant coherent puffball growth.

Synthetic sucrose solution: Moderate sediment of minute round white colonies.

Synthetic glycerol solution: Light white fluffy colonies, minute and in clusters.

Inspissated serum: Innumerable colorless pinpoint colonies; scant white aerial mycelium; after 15 days colonies large, hollow on reverse side; margin depressed; no liquefaction.

Dorset's egg medium: Minute, cream-colored, elevated colonies, becoming golden-brown, raised, convoluted.

Milk: Coagulated; brownish surface ring.

Litmus milk: No change in reaction.

Potato plug: Yellowish growth in thin line, terminal portion tending to be piled up, scant white aerial mycelium at top of slant; after 12 days, growth abundant, golden-brown, confluent, partly honey-combed, partly piled up.

Starch not hydrolyzed.

Tyrosine agar: Reaction negative.

Source: Human spleen in a case of acholuric jaundice.

62. **Streptomyces africanus** (Pijper and Pullinger) *comb. nov.* (*Nocardia africana* Pijper and Pullinger, Jour. Trop. Med. and Hyg., *30*, 1927, 153; *Actinomyces africanus* Nannizzi, in Pollaci, Tratt. Micopat. Umana, *4*, 1934, 8.) From Latin *Africanus*, relating to Africa.

Description from Erikson, Med. Res. Counc. Spec. Rept. Ser. 203, 1935, 18.

Unicellular branching mycelium forming small dense pink colonies with short straight sparse white aerial mycelium.

Gelatin: Irregular pink flakes; no liquefaction.

Agar: A few flat pink discoid colonies.

Glucose agar: Minute red discrete round colonies and piled up paler pink mass with thin white aerial mycelium.

Glycerol agar: After 2 weeks, small heaped-up colorless masses with pink tinge around the colorless colonies, margin depressed; after 3 weeks, abundant, piled up, pale pink growth.

Ca-agar: After 1 week, small, round, colorless colonies with red centers, margins submerged; after 2 weeks, growth bright cherry-red, confluent, with colorless margin.

Dorset's egg medium: Small colorless blister colonies, partly confluent; becoming wrinkled, depressed into medium; slight liquefaction.

Serum agar: Irregularly round, raised, wrinkled, colorless colonies; becoming dry, pink and flaky; later piled up, brownish, friable.

Inspissated serum: After one week, smooth, round, colorless colonies with submerged margin, in confluent patches pink and pitted into medium; after 2 weeks, medium broken up, slight liquefaction; after 3 weeks, liquid dried up, colonies umbilicated, raised, dry and friable.

Broth: Small pink colonies embedded in coherent flocculent mass.

Synthetic sucrose solution: Small pink granules in sediment after 1 week; colonies of medium size, coherent, after 3 weeks.

Potato agar: Bright red growth, small round colonies with colorless submerged margins, and piled up patches with stiff sparse white aerial mycelium.

Litmus milk: Bright red surface growth, liquid unchanged after one month; liquid opaque reddish-purple after 2 months; hydrolyzed, clear wine-red after 3 months.

Source: From a case of mycetoma of a foot in South Africa.

63. **Streptomyces gallicus** (Erikson) *comb. nov.* (*Actinomyces gallicus* Erikson, Med. Res. Counc. Spec. Rept. Ser. 203, 1935, 36.) From Latin *gallicus*, of the Gauls (French).

Description from Erikson (*loc. cit.*, p. 24).

Mycelium shows lateral highly refractive bodies which appear almost identical with the singly situated spores found in *Micromonospora chalceae*.

Gelatin: Scant irregular pink growth; liquefaction very slow, only slight degree in 20 days.

Agar: A few transparent minute pink colonies; growth becomes partly confluent.

Glucose agar: No growth.

Glycerol agar: No growth.

Czapek's agar: No growth.

Coon's agar: Minute colorless to pinkish colonies.

Ca-agar: Glossy pink pinhead colonies.

Potato agar: Pale pink, moist, granular growth.

Serum agar: Pinpoint colonies, pink, shining.

Blood agar: Abundant growth, minute, discrete, round, pink colonies, some aggregated in confluent narrow bands. No hemolysis.

Dorset's egg medium: Minute colonies, becoming confluent, tangerine-colored.

Inspissated serum: Abundant, pink, membranous growth, becoming reddish-brown; later discrete colonies at margin, clear on reverse side. No liquefaction.

Broth: Pinkish flakes.

Synthetic sucrose solution: A few fine white flocculi.

Synthetic glycerol solution: A few small round white colonies.

Milk: Coagulated; peptonized; yellowish-pink surface ring.

Litmus milk: No coagulation or peptonization; no change in color.

Potato plug: Very slow growth, a few minute translucent pink colonies after 16 days; after 21 days, considerable increase in number of colonies, still small and discrete. After 2 months, colonies 1 to 2 mm in diameter, bright coral, tending to be umbilicated and heaped up.

Tyrosine agar: Reaction negative.

Source: From blood culture in a case of Banti's disease.

64. **Streptomyces pelletieri** (Laveran) *comb. nov.* (*Micrococcus pelletieri* Laveran, Compt. rend. Soc. Biol., Paris, *61*, 1906, 340; *Oospora pelletieri* Thiroux and Pelletier, Bull. Soc. path. exot., *5*, 1912, 585; *Nocardia pelletieri* Thiroux, see Pinoy, Bull. Inst. Past., *11*, 1913, 935; *Discomyces pelletieri* Brumpt, Précis de Parasitol., Paris, 2nd ed., 1913, 970; *Actinomyces pelletieri* Brumpt, *ibid.*, 4th ed., 1927, 1204.) Named for M. Pelletier who first isolated this species.

Description from Erikson, Med. Res. Council Spec. Rept. Ser. 203, 1935, 21.

Thiroux and Pelletier (Bull. Soc. path. exot., *5*, 1912, 585) considered that their cultures resembled *Nocardia madurae*, but they grew the organism only on Sabouraud's gelatin, on which it appeared in a constantly red, easily detachable form. *Nocardia indica* was regarded as identical by Pinoy, although in the original description by Laveran the organism was called *Micrococcus pelletieri*, owing to the fact that no mycelium was seen, merely coccoid bodies. *Nocardia genesii* Froes (Bull. Inst. Past., *29*, 1931; 1158) is described as closely allied, the distinction being founded upon the fact that the red grains were smaller in size and much more numerous, but no cultural details are given.

Mycelium composed of slender straight and not very long filaments, forming small dense pink colonies with a few short straight isolated aerial branches.

Gelatin: Slight liquefaction; few pink flakes; later almost completely liquefied.

Agar: Minute colorless colonies and piled up pale pink masses.

Glucose agar: Poor growth, a few minute pink colonies.

Glycerol agar: Poor growth, a few moist pink colonies.

Ca-agar: Colorless small colonies; after 1 week, confluent skin, pink, buckled; medium discolored later.

Coon's agar: Poor growth, cream-colored with pink center, mostly submerged.

Potato agar: Colorless blister colonies; after 3 weeks, colonies larger, showing concentric zones, submerged margins and occasional zone or tuft of white aerial mycelium, pinkish coloration.

Dorset's egg medium: Abundant, wrinkled, pink skin with small discrete colonies at margin in six days; later surface rough, mealy; considerable liquefaction in 17 days.

Serum agar: Moist cream-colored growth tending to be heaped up, discrete colonies at margin; becoming umbilicated.

Inspissated serum: Round, moist, colorless colonies.

Blood agar: At first a few pinhead, cream-colored colonies, no hemolysis; later colonies dense, button-shaped, with narrow fringed margin.

Broth: Small, minute, pink, clustered colonies.

Synthetic sucrose solution: Small, pink colonies in sediment; later minute colonies adhering to side of tube.

Milk: Soft curd; half-digested; peptonization complete in 20 days.

Litmus milk: Pink surface growth, semi-solid, no color change; after 20 days, coagulum cleared, liquid purple.

Potato plug: After one month growth sparse, yellowish-pink, irregularly piled up, portions with scant white aerial mycelium; after 6 months abundant highly piled up small rounded pink

masses, scant white aerial mycelium persistent.

Source: From a case of crimson-grained mycetoma in Nigeria (E. C. Smith, Trans. R. Soc. Trop. Med. Hyg., *22*, 1928, 157).

Habitat: Human infections so far as known.

65. **Streptomyces listeri** (Erikson) *comb. nov.* (*Actinomyces listeri* Erikson, Med. Res. Council Spec. Rept. Ser. 203, 1935, 36.) Named for Dr. Joseph Lister, the father of antiseptic surgery.

Description from Erikson (*loc. cit.*, p. 23).

Long slender filaments, many loosely wavy, forming a dense spreading mycelium which rapidly grows into a membrane on most media. Aerial mycelium very slow and inconstant in appearance, short and straight, conidia oval.

Gelatin: Slight liquefaction; round white surface colonies; after 45 days, confluent skin, almost completely liquefied.

Agar: Smooth, round, moist, cream-colored, margin depressed, center elevated, closely adherent; becoming umbilicated, with a myceloid margin.

Glucose agar: Cream-colored, glistening, pinpoint colonies; later aggregated in convoluted skin.

Glycerol agar: Abundant, moist, cream-colored growth, colonies elevated, piled up; powdery white aerial mycelium. After 20 days, skin deeply buckled; colorless with exuded drops.

Ca-agar: Poor growth, a slight biscuit-colored membrane.

Potato agar: After one week, extensive growth, colorless submerged colonies, warted surface; dirty pink coloration after 2 weeks; scant white aerial mycelium after 4 months.

Dorset's egg medium: No growth.

Blood agar: Small, round, cream-colored colonies, smooth translucent surface; no hemolysis.

Serum agar: Small, irregular, moist, cream-colored colonies, tending to be heaped up; later somewhat transparent.

Inspissated serum: Abundant growth, colorless shiny colonies, centrally elevated, becoming confluent.

Broth: Small, round, white colonies in sediment.

Glucose broth: Small, white, nodular colonies; later abundant flocculi.

Synthetic sucrose solution: Delicate white colonies in suspension and in sediment.

Litmus milk: Coagulation. No change in reaction.

Potato plug: Abundant, dull, brownish, wrinkled skin with white aerial mycelium; large, stellate, fluffy, white colonies in liquid at base.

Source: From human material. Strain from Lister Collection.

Habitat: From human infections so far as known.

66. **Streptomyces upcottii** (Erikson) *comb. nov.* (A new pathogenic form of *Streptothrix*, Gibson, Jour. Bact. and Path., *23*, 1920, 357; *Actinomyces upcottii* Erikson, Med. Res. Council Spec. Rept. Ser. 203, 1935, 36.) Named for Dr. Harold Upcott, the surgeon who first secured the culture.

Description from Erikson (*loc. cit.*, p. 22).

Filaments characteristically long, straight, much interwoven and ramified; typical unicellular mycelium, usually forming medium to large heavy cartilaginous colonies. Gibson states that the threads vary in thickness and show septa, but this has not been confirmed. A very slight transient aerial mycelium appeared on one agar slope, but this has not been repeated on any slide microculture on any medium. Slightly acid-fast.

Gelatin: Abundant flocculent growth along streak, round cream-colored colonies on surface. Partly liquefied in 14 days; complete liquefaction in 2 months.

Agar: Smooth, shining, round, cream-colored colonies, margin submerged,

scant white aerial mycelium in one week; colonies large (up to 10 mm in diameter), centers elevated, greenish tinge, very sparse aerial mycelium in two weeks; the aerial mycelium disappears and large radial grooves appear in most colonies in 3 weeks.

Glucose agar: Smooth, round, cream-colored colonies, margin depressed, centers elevated, hollow on reverse side; later a coherent membranous growth, piled up, yellowish.

Glycerol agar: Small, round, cream-colored, glistening colonies, heavy texture, margins submerged; later, colonies umbilicated, tending to be piled up; after 6 weeks, growth very much convoluted and raised, broad submerged margin, slightly reddish medium.

Coon's agar: Small, radiating, white colonies, growth mostly submerged.

Ca-agar: Small, colorless membranous growth with undulating margin; later, centrally depressed into medium.

Potato agar: Poor growth, small, colorless blister colonies, medium slightly discolored.

Dorset's egg medium: Round, flat, colorless, scale-like colonies, some marked by concentric rings and slightly hollowed in center; growth becomes yellow-brown.

Serum agar: Large colonies (3 to 4 mm in diameter), colorless, granular, centrally elevated, depressed at margin, resembling limpets.

Blood agar: Large drab heavily textured colonies; no aerial mycelium; no hemolysis.

Broth: Large coherent mass composed of fluffy colonies.

Synthetic sucrose solution: Fair growth, minute white colonies.

Carrot plug: Colorless, spreading, moist, wrinkled growth in six weeks; later a dull greenish-brown, moist, very much wrinkled and depressed skin.

Source: From the spleen in a case of acholuric jaundice.

Habitat: From human infections so far as known.

67. **Streptomyces hortonensis** (Erikson) *comb. nov.* (*Actinomyces horton* Erikson, Med. Res. Council Spec. Rept. Ser. 203, 1935, 36.) Named for the Horton War Hospital at Epsom, England from which the culture was obtained.

Description from Erikson (*loc. cit.*, p. 22).

Typical germination into very slow growing unicellular mycelium composed of long slender straight branching filaments. Very sparse straight aerial mycelium produced only once on potato. Non-acid-fast.

Gelatin: Round cream-colored colonies on surface and a few mm below. No liquefaction.

Agar: Very slow growth, a few smooth cream-colored coiled colonies in 19 days; after 2 months, liberal, irregular, convoluted growth.

Glucose agar: Coiled and heaped up cream-colored translucent masses; after 2 months, growth rounded, elevated, ridged outwards from hollow center.

Glycerol agar: Coiled, colorless, lustrous patches, isolated colony with central depression.

Serum agar: Poor growth, small amorphous cream-colored mass.

Inspissated serum: Intricately coiled cream-colored growth. No liquefaction.

Broth: Flakes.

Synthetic sucrose solution: Poor growth, a few flakes.

Synthetic glycerol solution: Delicate white flocculi at base.

Litmus milk: Green surface growth, liquid hydrolyzed, partly clear purple; later decolorized, brown.

Potato agar: Colorless blister colonies in one week; dull green heaped and coiled mass after 3 weeks; medium becomes slightly discolored.

Potato plug: After 3 weeks, abundant, colorless, umbilicated, round colonies, some coiled in raised masses; later, liberal olive-green growth, piled up, dense, velvety gray-green aerial mycelium at top of slant, small round fluffy white colonies in liquid at base.

Source: From pus containing typical actinomycotic granules from parotid abscess.

Habitat: From human infections so far as known.

68. **Streptomyces gibsonii** (Erikson) *comb. nov.* (*Actinomyces gibsonii* Erikson, Med. Res. Council Spec. Rept. Ser. 203, 1935, 36.) Named for Prof. Gibson of Oxford.

Description from Erikson (*loc. cit.*, p. 15).

Young growing mycelium branches profusely at short intervals; later grows out into long frequently wavy filaments; twisted hyphae also seen on water agar. Power of producing aerial mycelium apparently lost.

Gelatin: Dull white flakes sinking as medium liquefies; liquefaction complete in 12 days.

Agar: Small, cream-colored, depressed, partly confluent colonies, becoming an extensive wrinkled cream-colored skin.

Glucose agar: Cream-colored wrinkled membranous growth.

Potato agar: Wrinkled glistening membranous growth.

Serum agar: Small moist cream-colored colonies growing into medium.

Dorset's egg medium: Small, round, smooth, colorless colonies with conically elevated centers.

Inspissated serum: Innumerable colorless pinpoint colonies with scant white aerial mycelium at top; after 8 days, a coherent wrinkled skin with brownish-red discoloration at reverse, medium becoming transparent; completely liquefied, pigmented brown in 15 days.

Blood agar: Yellowish confluent bands, irregularly wrinkled, with small discrete colonies, clear hemolytic zone.

Broth: Sediment of flocculi, some round and fan-shaped colonies.

Synthetic sucrose solution: Very delicate white flocculi.

Potato plug: No growth.

Starch not hydrolyzed.

Milk: Coagulated; partly peptonized.

Tyrosine agar: Negative reaction.

Source: From the spleen in a case of acholuric jaundice. Injected into a monkey, and reisolated.

Habitat: From human infections so far as known.

69. **Streptomyces beddardii** (Erikson) *comb. nov.* (*Actinomyces beddardii* Erikson, Med. Res. Council Spec. Rept. Ser. 203, 1935, 36.) Presumably named for the surgeon who first secured the culture.

Description from Erikson (*loc. cit.*, p. 13).

Rapidly growing, dense, spreading mycelium composed of very long slender filaments, many wavy or closely coiled, particularly on glucose agar; spirals less marked or lacking on poorer nutritive media like synthetic glycerol agar or water agar. Aerial mycelium sparse, short, straight on synthetic glycerol agar, much slower and more plentiful on glucose agar; later shows long, very fine spirals breaking up into small oval conidia; aerial hyphae straighter and more branched with shorter conidiophores on starch agar. Non-acid-fast.

Gelatin: Dull white flakes sinking to bottom as medium liquefies; liquefaction complete in 8 days.

Agar: Colorless, coherent, wrinkled, membranous growth with submerged margin; after 3 months, medium discolored, scant white aerial mycelium at top.

Glucose agar: Wrinkled membranous growth; after 2 months, scant white aerial mycelium.

Glycerol agar: Small, cream-colored, discrete colonies becoming confluent, under surface much buckled.

Potato agar: Moist, cream-colored skin, convoluted, closely adherent.

Ca-agar: Extensive, moist, cream-colored, wrinkled, membranous growth.

Coon's agar: Scant, cream-colored, membranous growth.

Starch agar: Spreading, colorless growth, considerable white aerial mycelium.

Blood agar: Hemolysis. Growth in uniformly striated colorless bands, occasional round colonies at margin.

Dorset's egg medium: Extensive, very wrinkled, membranous growth, surface bright yellow. After 2 months, considerable liquefaction.

Serum agar: Wrinkled, glistening, cream-colored, membranous growth.

Inspissated serum: Colorless smeary growth, reverse becoming transparent, starting to liquefy at base; completely liquefied and brown in 12 days.

Broth: Suspended and sedimented colorless flocculi, some small round colonies.

Synthetic sucrose solution: Abundant white colonies in coherent mass near bottom of tube; large shell-shaped masses.

Synthetic glycerol solution: At first, a few round white colonies in suspension; later, large branched feathery mass at bottom.

Milk: Coagulated; later peptonized.

Litmus milk: Medium deep blue, becoming hydrolyzed to clear purple.

Potato plug: Colorless moist membranous growth with scant white aerial mycelium at top of plug.

Starch is hydrolyzed.

Tyrosine agar: Reaction negative.

Source: Human spleen in a case of spleenic anemia.

Habitat: From human infections so far as known.

70. **Streptomyces kimberi** (Erikson) *comb. nov.* (*Actinomyces kimberi* Erikson, Med. Res. Council Spec. Rept. Ser. 203, 1935, 36.) Presumably named for the surgeon who first secured the culture.

Description from Erikson (*loc. cit.*, p. 14).

Mycelium of long straight profusely branching filaments forming circumscribed colonies on all media with abundant production of short straight and branched aerial mycelium; small round conidia. Non-acid-fast.

Gelatin: Liquefied. Smooth shining colonies becoming powdery white with aerial mycelium, floating on liquefied medium. No pigmentation.

Agar: Smooth round moist cream-colored colonies, 1 mm in diameter; after 17 days, white powdery aerial mycelium.

Glucose agar: Discrete cream-colored colonies becoming confluent, white aerial mycelium.

Glycerol agar: Moist cream-colored colonies becoming confluent, white aerial mycelium.

Potato agar: Extensive growth covered by white powdery aerial mycelium; large colorless exuded droplets.

Wort agar: Heavy brownish lichenoid colony; after 30 days, a white aerial mycelium.

Ca-agar: Dull cream-colored scaly growth, covered by chalky white aerial mycelium.

Coon's agar: Extensive growth, white aerial mycelium in annular arrangement.

Czapek's agar: Small colonies covered with white aerial mycelium.

Blood agar: Many large colonies, cream-colored, tough, smooth, glistening, with margin depressed; no hemolysis.

Serum agar: Moist, cream-colored honeycombed skin, scant white aerial mycelium.

Dorset's egg medium: Closely adherent scale-like colonies, centrally elevated, with white aerial mycelium.

Inspissated serum: Rapid spreading growth, discrete round colonies at margin, completely covered with white aerial mycelium, colorless transpired drops; slight softening at base.

Broth: Small round colonies in sediment in 2 days; supernatant colonies with white aerial mycelium and large hollow flakes in sediment in 15 days; occasional reddish-brown coloration.

Synthetic sucrose solution: Round white colonies at bottom; later small stellate colonies in suspension and a few supernatant with white aerial mycelium.

Synthetic glycerol solution: Round white colonies at bottom; later coherent mulberry-like mass composed of fluffy

round portions; after 15 days, irregular wispy flocculi and large coherent mass.

Milk: Coagulation; no peptonization; initial pinkish-brown ring descends until medium is dark brown throughout (2 months).

Litmus milk: Blue coloration, hydrolyzed to clear purple in 2 months.

Starch not hydrolyzed.

Tyrosine agar: Reaction negative.

Source: Blood culture of a woman with acholuric jaundice.

Habitat: From human infections so far as known.

71. **Streptomyces somaliensis** (Brumpt) *comb. nov.* (*Indiella somaliensis* Brumpt, Arch. Parasit., Paris, *10*, 1906, 489; *Discomyces somaliensis* Brumpt, Précis de Parasitologie, Paris, 2nd ed., 1913, 967; *Indiellopsis somaliensis* Brumpt, *ibid.*; *Nocardia somaliensis* Chalmers and Christopherson, Ann. Trop. Med. and Parasit., *10*, 1916, 239; *Streptothrix somaliensis* Miescher, Arch. Derm. Syphilis, *124*, 1917, 297; *Actinomyces somaliensis* St. John-Brooks, Med. Res. Council Syst. of Bact., London, *8*, 1931, 75.) Named for the country of origin, French Somaliland.

Description from Erikson (Med. Res. Council Spec. Rept. Ser. 203, 1935, 17).

Simple branching unicellular mycelium with long straight filaments, forming circumscribed colony crowned with short straight aerial mycelium.

Gelatin: Cream-colored colonies, medium pitted; complete liquefaction in 10 days; hard black mass at bottom.

Agar: Abundant yellowish granular growth with small discrete colonies at margin; later growth colorless, colonies umbilicated.

Glucose agar: Poor growth, moist cream-colored elevated patch.

Glycerol agar: Abundant growth, minute round to large convoluted and piled up masses, colorless to dark gray and black.

Ca-agar: Round cream-colored colonies, depressed, umbilicated, piled up, thin white aerial mycelium; colonies become pale brown.

Potato agar: Small round colorless colonies, zonate margin depressed, confluent portion dark greenish-black.

Blood agar: Small dark brown colonies, round and umbilicated, piled up confluent bands, reverse red-black; hemolysis.

Dorset's egg medium: Extensive colorless growth, partly discrete; becoming opaque, cream-colored, very wrinkled; later rough, yellow, mealy, portion liquid.

Serum agar: Spreading yellow-brown skin, intricately convoluted.

Inspissated serum: Cream-colored coiled colonies, medium pitted, transparent and slightly liquid.

Broth: A few round white colonies at surface, numerous fluffy masses in sediment; later large irregular mass breaking into wisps.

Synthetic sucrose solution: Minute round white fluffy colonies in sediment; after 17 days, scant wispy growth.

Milk: Soft semi-liquid coagulum which undergoes digestion; heavy wrinkled surface pellicle, completely liquefied in 12 days.

Litmus milk: Soft coagulum, partly digested, blue surface ring; clear liquid in 12 days.

Potato plug: Abundant growth, colonies round and oval, partly piled up in rosettes, frosted with whitish-gray aerial mycelium, plug discolored; after 16 days, aerial mycelium transient, growth nearly black.

Although *Streptomyces somaliensis* has been known for a long time, there has been until recently no detailed descriptions of the organism beyond the fact that it possesses a distinctly hard sheath around the grain which is insoluble in potash and eau de javelle. The rare occurrence of septa and occasional intercalary chlamydospores is reported by Brumpt (Arch. Parasit., *10*, 1905, 562), but has not been confirmed by Erikson (*loc. cit.*). Chalmers and Christopherson (Ann. Trop. Med. Parasit., *10*, 1916, 223)

merely mentioned the growth on potato as yellowish-white and lichenoid without describing any aerial mycelium. Balfour in 1911 reported a case but gave no data, and Fülleborn limited his description to the grain (Arch. Schiffs. Trop. Hyg., *15*, 1911, 131). This species was first placed in *Indiella*, a genus of fungi, by Brumpt (1906, *loc. cit.*). Later Brumpt (1913, *loc. cit.*) proposed a new genus or subgenus, *Indiellopsis*, containing the single species *Indiellopsis somaliensis*.

Source: Yellow-grained mycetoma, Khartoum (Balfour, 4th Rept. Wellcome Trop. Res. Lab., A. Med., London, 1911, 365).

Habitat: This condition has been observed by Baufford in French Somaliland, by Balfour (*loc. cit.*) in the Anglo-Egyptian Sudan, by Fülleborn (*loc. cit.*) in German So. West Africa and by Chalmers and Christopherson (*loc. cit.*) in the Sudan.

72. **Streptomyces panjae** (Erikson) *comb. nov.* (*Actinomyces panja* Erikson, Med. Res. Council Spec. Rept. Ser. 203, 1935, 36.) Named for Dr. Panja who first secured the culture.

Description from Erikson (*loc. cit.*, p. 16).

Unicellular mycelium with slender branching filaments; very small round colonies; no aerial mycelium visible on any medium, but occasional isolated aerial branches. Non-acid-fast.

Gelatin: Complete liquefaction in 4 days.

Agar: Colorless irregularly piled up convoluted growth; after 1 month, easily detachable, brownish.

Glucose agar: Small colorless coiled mass in 1 week; heaped up green growth in 2 weeks.

Glycerol agar: Poor growth, scant colorless patch.

Ca-agar: Colorless to pink spreading growth with minute discrete colonies at margin; after 2 weeks, bright red mass, buckled and shining, colorless submerged margin.

Coon's agar: Small submerged colorless growth.

Potato agar: Small elevated convoluted colorless masses with purple tinge in center.

Dorset's egg medium: Small round tough colorless colonies, margin well embedded; after 3 weeks, colonies elevated, warted, darkened, medium discolored and broken; slight degree of liquefaction, medium dark brown.

Serum agar: Colorless, glistening, piled up, convoluted mass.

Inspissated serum: Small round blister colonies and irregularly convoluted patches deeply sunk in pitted medium; after 2 weeks, medium transparent, slight degree of liquefaction.

Broth: Flakes and minute colorless colonies.

Glucose broth: Poor growth, scant flakes, pinkish.

Synthetic sucrose solution: Pinkish flocculi; after 3 weeks, moderate growth, minute colorless colonies.

Milk: Coagulation; pale green surface growth; mostly digested in 2 weeks.

Litmus milk: Soft coagulum, color unchanged; after 2 months, mostly digested, residue coagulum light purple.

Source: From an ulcer of the abdominal wall, Calcutta.

73. **Streptomyces willmorei** (Erikson) *comb. nov.* (*Actinomyces willmorei* Erikson, Med. Res. Council Spec. Rept. Ser. 203, 1935, 36.) Named for Dr. Willmore who isolated the culture.

Description from Erikson (*loc. cit.*, p. 19).

Germination usual, but growing unicellular mycelium frequently branches at very short intervals, presenting peculiar clubbed and budding forms with occasional separate round swollen cells which may represent the cystites of other writers. The filaments are characteristically long, homogeneous, and much interwoven. Aerial mycelium is profuse

in most media, with a marked tendency to produce loose spirals (water and synthetic glycerol agar) with chains of ellipsoidal conidia. Thick aerial clusters may also be formed.

Gelatin: Minute colorless colonies; liquefaction.

Agar: Heavy folded colorless lichenoid growth, rounded elevations covered with white aerial mycelium; later, submerged margin, round confluent growth, aerial mycelium marked in concentric zones.

Glucose agar: Colorless wrinkled confluent growth with smooth entire margin, large discrete colonies like flat rosettes; after 4 months, scant white aerial mycelium.

Glycerol agar: Round smooth cream-colored colonies, heavy texture, margin submerged, stiff sparse aerial spikes; after 3 weeks, colonies large (up to 10 mm in diameter).

Ca-agar: Spreading colorless growth, pitting medium, submerged undulating margin; very scant white aerial mycelium.

Coon's agar: Opaque white growth extending irregularly (up to 3 mm) into medium, margin smooth and submerged, center raised, greenish tinge covered with white aerial mycelium; after 3 weeks, margin green, central mass covered by gray aerial mycelium.

Potato agar: Fair growth, partly submerged, covered with grayish-white aerial mycelium; medium becomes discolored.

Blood agar: Heavily textured small drab colonies, aerial mycelium microscopical; no hemolysis.

Dorset's egg medium: Large, round, colorless, scale-like colonies, radially wrinkled; growth brownish, medium discolored in 2 weeks.

Serum agar: Smooth colorless discoid colonies; marked umbilication after 2 weeks.

Broth: Large fluffy white hemispherical colonies, loosely coherent.

Synthetic sucrose solution: A few large round white colonies with smooth partly zonate margins, lightly coherent in sediment; later smaller colonies in suspension attached to side of tube.

Milk: Coagulation; one-third peptonized.

Carrot plug: Colorless raised colonies with powdery white aerial mycelium; after 1 month, very much piled up, aerial mycelium gray; after 2 months, superabundant growth around back of plug, confluent, greatly buckled, all-over gray aerial mycelium.

Source: Streptothricosis of liver (Willmore, Trans. Roy Soc. Trop. Med. Hyg., *17*, 1924, 344).

Habitat: From human infections so far as known.

***Appendix:** The following names have been used for species of *Streptomyces*. Many of them are regarded as new by their authors merely because they were isolated from a new type of lesion, or from some animal other than man. Others are inadequately described species from air, soil or water. Relationships to other better described species are usually very obscure. Some of the species listed here may belong in the appendix to the genus *Nocardia*.

Actinomyces aerugineus Wollenweber. (Arb. d. Forschungsinst. f. Kartoffelbau, 1920, 16.) From deep scab on potato.

Actinomyces albidofuscus Neukirch. (*Actinomyces albido fuscus* Berestnew, Inaug. Diss., Moskow, 1897; see Cent. f. Bakt., I Abt., *24*, 1898, 707; Neukirch, Inaug. Diss., Strassburg, 1902, 3.) From grain.

Actinomyces albidus Duché. (Encyclopédie Mycologique, Paris, *6*, 1934, 266.)

Actinomyces alboatrus Waksman and

*** This appendix was originally prepared by Prof. S. A. Waksman and Prof. A. T. Henrici, May, 1943; it has been developed further by Mrs. Eleanore Heist Clise, Geneva, New York, August, 1945.**

Curtis. (Soil Science, *1*, 1916, 117.) From adobe soil.

Actinomyces alboviridis Duché. (Encyclopédie Mycologique, Paris, *6*, 1934, 317.)

Actinomyces albus (Rossi Doria) Gasperini. (*Streptotrix* (sic) *alba* Rossi Doria, Ann. d. Ist. d'Ig. sper. d. Univ. di Roma, *1*, 1891, 421; Streptothrix Nos. 2 and 3, Almquist, Ztschr. f. Hyg., *8*, 1890, 189; *Oospora doriae* Sauvageau and Radais, Ann. Inst. Past., *6*, 1892, 251; *Actinomyces bovis albus* Gasperini, Atti Soc. Tosc. Scienz. Nat., P. V., *9*, 1894; Gasperini, Cent. f. Bakt., *15*, 1894, 685.) A general name applied to the most common streptomyces in air and water.

Actinomyces albus asporogenes Berestnew. (Inaug. Diss., Moskow, 1897; see Cent. f. Bakt., I Abt., *24*, 1898, 708.)

Actinomyces albus var. *ochraleucus* Wollenweber. (Arb. d. Forschungsinst. für Kartoffelbau, 1920, 16.)

Actinomyces albus - vulgaris Ciani. (Quoted from Baldacci, Boll. Sez. Ital. Soc. Internaz. di Microbiol., *9*, 1937, 140.)

Actinomyces almquisti Duché. (Duché, Encyclopédie Mycologique, Paris, *6*, 1934, 278.) From culture labeled *Actinomyces albus* (Krainsky) Waksman and Curtis (Soil Sci., *1*, 1916, 117; said to resemble *Streptothrix* No. 1, Almquist, Ztschr. f. Hyg., *8*, 1890, 189).

Actinomyces alni Peklo. (Cent. f. Bakt., II Abt., *27*, 1910, 451.) From swellings of the roots of *Alnus glutinosa*.

Actinomyces annulatus Wollenweber. (Arb. Forschungsinst. für Kartoffelbau, 1920, 16.) From dark-colored potato stem.

Actinomyces (*Streptothrix*) *annulatus* Beijerinck. (Folia Microbiologica, *1*, 1912, 4.)

Actinomyces aurea (du Bois Saint Sévérin) Ford. (*Streptothrix aurea* du Bois Saint Sévérin, Arch. de méd. nav., 1895, 252; *Nocardia aurea* Castellani and Chalmers, Man. Trop. Med., 2nd ed., 1913, 818; *Oospora aurea* Sartory, Champ. Paras. Homme et Anim., 1923, 818; Ford, Textb. of Bact., 1927, 220; not *Actinomyces aureus* Waksman and Curtis, Soil Science, *1*, 1916, 124.) Possibly synonymous with *Actinomyces aureus* Lachner-Sandoval, Die Strahlenpilze, 1893, according to Lieske, Morphol. u. Biol. d. Strahlenpilze, Leipzig, 1921, 26. Found in conjunctivitis.

Actinomyces bellisari Dodge. (*Streptothrix alba* Bellisari, Ann. Ig. Sperim., *14*, 1904, 467; *Oospora alba* Sartory, Champ. Paras. Homme et Anim., 1923, 819; Dodge, Medical Mycology, St. Louis, 1935, 744.) Isolated in a warehouse in Naples from the dust of cereal coming from California.

Actinomyces bovis var. *nigerianus* Erikson. (Med. Res. Council Spec. Rept. Ser. 203, 1935, 20 and 36.) From streptothricosis of the skin of cattle in Nigeria.

Actinomyces candidus (Petruschky) Bergey et al. (*Streptothrix candida* (Gedanensis II) Petruschky, Verhandl. d. Kongr. f. innere Med., 1898; see Petruschky, in Kolle and Wassermann, Handb. d. path. Mikroorg., 2 Aufl., *5*, 1913, 285 and 294; *Nocardia candida* Castellani and Chalmers, Man. Trop. Med., 2nd ed., 1913, 818; *Discomyces candidus* Brumpt, Précis de Parasitol., Paris, 3rd ed., 1922, 980; Bergey et al., Manual, 1st ed., 1923, 347.) From human lung.

Actinomyces carneus (Rossi Doria) Gasperini. (*Streptotrix carnea* Rossi Doria, Ann. Ist. d'Ig. sper. Univ. Roma, *1*, 1891, 415; Gasperini, *ibid.*, *2*, 1892, 222; *Oospora carnea* Lehmann and Neumann, Bakt. Diag., 1 Aufl., *2*, 1896, 388; *Cladothrix carnea* Macé, Traité Pratique de Bact., 4th ed., 1901, 1096; *Discomyces carneus* Brumpt, Précis de Parasitol., 2nd ed., 1913, 976; *Nocardia carnea* Castellani and Chalmers, Man. Trop. Med., 2nd ed., 1913, 818.) From air.

Actinomyces carnosus Millard and Burr. (Ann. Appl. Biol., *13*, 1926, 601.) From scab on potato.

Actinomyces casei Bernstein and Morton. (Jour. Bact., *27*, 1934, 625.) Thermophilic. From pasteurized cheese.

Actinomyces cati (Rivolta) Gasperini. (*Discomyces cati* Rivolta, 1878; Gasperini, Cent. f. Bakt., *15*, 1894, 684.) Cause of a disease in a cat.

Actinomyces cerebriformis Namyslowski. (Namyslowski, Cent. f. Bakt., I Abt., Orig., *62*, 1912, 564; *Streptothrix cerebriformis* Chalmers and Christopherson, Ann. Trop. Med. and Parasit., *10*, 1916, 273; *Nocardia cerebriformis* Vuillemin, Encyclopédie Mycologique, Paris, *2*, 1931, 126.) From an infection of the cornea of the human eye.

Actinomyces cereus. (Quoted from Lieske, Morphol. u. Biol. d. Strahlenpilze, Leipzig, 1921, 33.)

Actinomyces chromogenus (Gasperini) Gasperini. (*Streptotrix nigra* Rossi Doria, Ann. d. Ist. d'Ig. sper. d. Univ. di Roma, *1*, 1891, 419; *Streptotrix cromogena* (sic) Gasperini, according to Rossi Doria, *idem*; Gasperini, *ibid.*, *2*, 1892, 222; *Oospora chromogenes* Lehmann and Neumann, Bakt. Diag., 1 Aufl., *2*, 1896, 389; *Cladothrix chromogenes* Macé, Traité Pratique de Bact., 4th ed., 1901, 1075; *Actinomyces niger* Brumpt, Précis de Parasitol., Paris, 4th ed., 1927, 1206.) A general name for streptomyces from air producing a dark chromogenesis on protein media.

Actinomyces cinereonigeraromaticus Neukirch. (*Actinomyces cinereus niger aromaticus* Berestnew, Inaug. Diss., Moskow, 1897; see Cent. f. Bakt., I Abt., *24*, 1898, 707; Neukirch, Inaug. Diss., Strassburg, 1902, 3; *Nocardia cinereonigra* Chalmers and Christopherson, Ann. Trop. Med. and Parasit., *10*, 1916, 271; *Streptothrix cinereonigra aromatica*, attributed to Berestnew by Chalmers and Christopherson, *idem*; *Actinomyces cinereo-niger*, quoted from Lieske, Morphol. u. Biol. d. Strahlenpilze, Leipzig, 1921, 33.) From grain.

Actinomyces citreus Gasperini. (Gasperini, Cent. f. Bakt., *15*, 1894, 684; *Streptothrix citrea* Kruse, in Flügge, Die Mikroorganismen, 3 Aufl., *2*, 1896, 63; not *Actinomyces citreus* Krainsky, Cent. f. Bakt., II Abt., *41*, 1914, 662.)

Actinomyces clavifer Millard and Burr. (Ann. Appl. Biol., *13*, 1926, 601.) From scab on potato and from soil.

Actinomyces coroniformis Millard and Burr. (Ann. Appl. Biol., *13*, 1926, 601.) From peat soil.

Actinomyces craterifer Millard and Burr. (Ann. Appl. Biol., *13*, 1926, 601.) From scab on potato.

Actinomyces cloacae Brussoff. (Cent. f. Bakt., II Abt., *49*, 1919, 97.) From mud.

Actinomyces cretaceus (Krüger) Wollenweber. (*Oospora cretacea* Krüger, Berichte der Versuchsstat. f. Zuckerrohrs, Kergok-Legal, 1890; Wollenweber, Arbeiten d. Forschungsinstitut für Kartoffelbau, 1920, 16.) From potato scab.

Actinomyces dicksonii Erikson. (Med. Res. Council Spec. Rept. Ser. 203, 1935, 17.)

Actinomyces elastica Söhngen and Fol. (Cent. f. Bakt., II Abt., *40*, 1914, 92.) From garden earth.

Actinomyces ferrugineus Naumann. (Kungl. Svenska Vetenskapsakad. Handl., I, *62*, Part 4, 1921, 45.) From Aneboda region of Sweden. Deposits ferric hydroxide about the mycelial threads.

Actinomyces filiformis (Boas) Nannizzi. (*Bacillus filiformis* Boas, 1897; not *Bacillus filiformis* Tils. Ztschr. f. Hyg., *9*, 1890, 294; not *Bacillus filiformis* Migula, Syst. d. Bakt., *2*, 1900, 387; *Nocardia filiformis* Vuillemin, Encyclopédie Mycologique, Paris, *2*, 1931, 132; Nannizzi, in Pollacci, Tratt. Micopat. Umana, *4*, 1934, 26.) From the human stomach.

Actinomyces fimbriatus Millard and Burr. (Ann. Appl. Biol., *13*, 1926, 601.) From scab on potato.

Actinomyces flavegriseus Duché. (Encyclopédie Mycologique, Paris, *6*, 1934, 341.) From volcanic soils (Martinique).

Actinomyces flavus Sanfelice. (Sanfelice, Cent. f. Bakt., I Abt., Orig., *36*, 1904, 359; *Streptothrix flava* Sanfelice, *ibid.*; not *Streptothrix flava* Chester, Manual Determ. Bact., 1901, 362; not *Actinomyces flavus* Krainsky, Cent. f.

Bakt., II Abt., *41*, 1914, 662.) From air.

Actinomyces flavus Millard and Burr. (Millard and Burr, Ann. Appl. Biol., *13*, 1926, 601; not *Actinomyces flavus* Sanfelice, Cent. f. Bakt., I Abt., Orig., *36*, 1904, 359; not *Actinomyces flavus* Krainsky, Cent. f. Bakt., II Abt., *41*, 1914, 662; not *Actinomyces flavus* Dodge, Medical Mycology, St. Louis, 1935, 752.) From scab on potato.

Actinomyces foersteri (Cohn) Gasperini. (*Streptothrix foersteri* Cohn, Beitr. z. Biol. d. Pflanz., *1*, Heft 3, 1875, 186; *Cladothrix foersteri* Winter, Die Pilze, in Rabenhorst's Kryptogamen-Flora, I Abt., *1*, 1884, 60; *Nocardia foersteri* Trevisan, I generi e le specie delle Batteriacee, 1889, 9; *Oospora foersteri* Sauvageau and Radais, Ann. Inst. Past., *6*, 1892, 252; Gasperini, Cent. f. Bakt., *15*, 1894, 684; *Discomyces foersteri* Gedoelst, Les champignons parasites de l'homme et des animaux domestiques. Brussels, 1902, 176; *Cohnistreptothrix foersteri* Pinoy, Bull. Inst. Pasteur, Paris, *11*, 1913, 937.) The first streptomyces to be described. Probably not identifiable. From an inflamed tear duct. Chalmers and Christopherson (Ann. Trop. Med. and Parasit., *10*, 1916, 273) include *Leptothrix oculorum* Sorokin, 1881 as a synonym of this species.

Actinomyces fusca Söhngen and Fol. (Cent. f. Bakt., II Abt., *40*, 1914, 87.) From garden earth.

Actinomyces gabritschewskii Neukirch. (*Actinomyces* of Gabritschewsky, Berestnew, Inaug. Diss., Moskow, 1897; see Cent. f. Bakt., I Abt., *24*, 1898, 708; Neukirch, Inaug. Diss., Strassburg, 1902, 3.) From water.

Actinomyces gedanensis (Löhlein) Bergey et al. (*Streptothrix gedanensis I*, Scheele and Petruschky, Verhandl. d. Kongr. f. innere Med., 1897, 550; *Streptothrix gedanensis* Löhlein, Ztschr. f. Hyg., *63*, 1909, 11; *Nocardia gedanensis* Chalmers and Christopherson, Ann. Trop. Med. and Parasit., *10*, 1916, 255; *Discomyces gedanensis* Brumpt, Précis de Parasitol., Paris, 3rd ed., 1922, 984; Bergey et al., Manual, 1st ed., 1923, 347.) From sputum of patient with chronic lung disease.

Actinomyces gibsoni Dodge. (*Streptothrix sp.* Gibson, Jour. Path. Bact., *23*, 1920, 357; *Oospora sp.* Sartory, Champ. Paras. Homme et Anim., 1923, 776; Dodge, Medical Mycology, St. Louis, 1935, 722.) See page 961.

Actinomyces gracilis Millard and Burr. (Ann. Appl. Biol., *13*, 1926, 601.) From scab on potato.

Actinomyces graminearum Berestnew. (Berestnew, Inaug. Diss., Moskow, 1897; see Cent. f. Bakt., I Abt., *24*, 1898, 707; *Nocardia graminarium* (sic) Chalmers and Christopherson, Ann. Trop. Med. and Parasit., *10*, 1916, 265; *Streptothrix graminarium* Chalmers and Christopherson, *idem.*) From grain.

Actinomyces graminis Topley and Wilson. (Aktinomyces, Bostroem, Beitr. path. Anat. u. Path., *9*, 1891, 1; Topley and Wilson, Princip. Bact. and Immun., 1st ed., *1*, 1931, 250; *Actinomyces bostroemi* Baldacci, Boll. Sez. Ital. Soc. Internat. Microbiol., *9*, 1937, 141.) From bovine actinomycosis.

Actinomyces gruberi Terni. (Terni, Cent. f. Bakt., *16*, 1894, 362; *Nocardia gruberi* Blanchard, in Bouchard, Traité Path. Gén., *2*, 1896, 855; *Streptothrix grueberi* (sic) Sanfelice, Cent. f. Bakt., I Abt., Orig., *36*, 1904, 356; *Oospora gruberi*, quoted from Nannizzi, Tratt. Micopat. Umana, *4*, 1934, 51.) From soil. Produces several pigments on culture media.

Actinomyces guignardi (Sauvageau and Radais) Ford. (*Oospora guignardi* Sauvageau and Radais, Ann. Inst. Past., *6*, 1892, 255; Ford, Textb. of Bact., 1927, 220.) From dust. Gasperini (*loc. cit.*) regards this as a possible synonym of *Actinomyces chromogenus*.

Actinomyces halotrichis ZoBell and Upham. (Bull. Scripps Inst. Oceanography Univ. California, *5*, 1944, 273.) From marine mud and kelp.

Actinomyces heimi Duché. (Encyclo-

pédie Mycologique, Paris, *6*, 1934, 359.)

Actinomyces hoffmanni (Gruber) Gasperini. (*Micromyces hofmanni* (sic) Gruber, Münch. med. Wochnschr., 1891; also Arch. f. Hyg., *16*, 1893, 35; *Oospora hoffmanni* Sauvageau and Radais, Ann. Inst. Past., *6*, 1892, 252; Gasperini, Cent. f. Bakt., *15*, 1894, 684; *Streptothrix hofmanni* Kruse, in Flügge, Die Mikroorganismen, 3 Aufl., *2*, 1896, 62; *Cladothrix hoffmanni* Macé, Traité Pratique de Bact., 4th ed., 1901, 1081.) Pathogenic. See page 976.

Actinomyces holmesi (Gedoelst) Nannizzi. (*Discomyces holmesi* Gedoelst, Champ. Paras. Homme et Anim., 1902; Nannizzi, Tratt. Micopat. Umana, *4*, 1934, 49.)

Actinomyces hominis Waksman. (Soil Science, *8*, 1919, 129.) Culture received from K. Meyer from Foulerton who isolated it in 1911 from an abscess of the palm. Waksman (*loc. cit.*) and Baldacci (Mycopathologia, *2*, 1940, 160) regard this as identical with Bostroem's organism (see *Actinomyces graminis* above) and Baldacci has renamed it *Actinomyces innominatus*.

Actinomyces incanescens Wollenweber. (Arb. Forschungsinst. für Kartoffelbau, 1920, 16.) From the soil of potato fields near Berlin.

Actinomyces intermedius (Krüger) Wollenweber. (*Oospora intermedia* Krüger, Berichte der Versuchsstat. f. Zuckerrohrs, Kergok-Legal, 1890; Wollenweber, Arb. d. Forschungsinst. für Kartoffelbau, 1920, 16.) From the soil of potato fields near Berlin.

Actinomyces interproximalis (Fennel) Ford. (*Streptothrix interproximalis* Fennel, Jour. Inf. Dis., *22*, 1918, 567; Ford, Textb. of Bact., 1927, 195.) From the mouth.

Actinomyces invulnerabilis (Acosta and Grande Rossi) Lachner-Sandoval. (*Cladothrix invulnerabilis* Acosta and Grande Rossi, Cronica medicoquirurgica de la Habana, No. 3, 1893; see Cent. f. Bakt., *14*, 1893, 14; *Streptothrix invulnerabilis* Kruse, in Flügge, Die Mikroorganismen, 3 Aufl., *2*, 1896, 64; Lachner-Sandoval, Ueber Strahlenpilze, Strassburg, 1898; *Nocardia invulnerabilis* Chalmers and Christopherson, Ann. Trop. Med. and Parasit., *10*, 1916, 271.) From river water.

Actinomyces krausei (Chester) Ford. (*Streptothrix* aus Eiter, Krause, Münch. med. Wchnschr., *46*, 1899, 749 and Cent. f. Bakt., I Abt., *26*, 1899, 209; also see Petruschky, in Kolle and Wassermann, 2 Aufl., *5*, 1913, 267; *Streptothrix krausei* Chester, Manual Determ. Bact., 1901, 364; *Nocardia krausei* Chalmers and Christopherson, Ann. Trop. Med. and Parasit., *10*, 1916, 263; *Discomyces krausei* Brumpt, Précis de Parasitol., Paris, 3rd ed., 1922, 993; Ford, Textb. of Bact., 1927, 208.) From actinomycotic pus.

Actinomyces lacertae Terni. (Terni, L'Officiale Sanitario, 1896, 160; *Streptothrix lacertae* Foulerton, in Allbutt and Rolleston, Syst. of Med., *2*, 1912, 309; *Oospora lacertae* Sartory, Champ. Paras. Homme et Anim., 1923, quoted from Nannizzi, Tratt. Micopat. Umana, *4*, 1934, 51.) From grayish nodules in the liver of Italian lizards (*Lacerta viridis* and *L. agilis*).

Actinomyces lathridii (Petruschky) Ford. (*Streptothrix lathridii* Petruschky, Verhandl. d. Kong. f. innere Med., 1898; Ford, *loc. cit.*, 205.) From the beetle, *Lathridius rugicollis*.

Actinomyces loidensis Millard and Burr. (Ann. Appl. Biol., *13*, 1926, 601.) From scab on potato.

Actinomyces luteo-roseus Sanfelice. (*Actinomyces bovis luteoroseus* Gasperini, Cent. f. Bakt., *15*, 1894, 684; Sanfelice, Cent. f. Bakt., I Abt., Orig., *36*, 1904, 355.) Isolated from actinomycotic lesion in cattle.

Actinomyces marginatus Millard and Burr. (Ann. Appl. Biol., *13*, 1926, 601.) From scab on potato.

Actinomyces marinolimosus ZoBell and

Upham. (Bull. Scripps Inst. Oceanography Univ. California, *5*, 1944, 256.) From marine mud.

Actinomyces melanoroseus Roisin. (Wisti Nauk Doslid. Kat. biol. Odessa, *1*, 1929, 60.)

Actinomyces metchnikovi (Sauvageau and Radais) Ford. (*Oospora metchnikowi* Sauvageau and Radais, Ann. Inst. Past., *6*, 1892, 242; Ford, *loc. cit.*, 220.) From water. Gasperini (*loc. cit.*) regards this organism as a possible synonym of *Actinomyces chromogenus*.

Actinomyces muris ratti Lieske. (*Streptothrix ratti* Schottmüller, Dermat. Wochnschr., *58*, 1914, Supplement, 77; *Streptothrix muris-ratti* Dick and Tunnicliff, Jour. Inf. Dis., *23*, 1918, 186; Lieske, Morphol. u. Biol. d. Strahlenpilze, Leipzig, 1921, 31; regarded as identical with *Streptobacillus moniliformis* Levaditi, Nicolau and Poincloux, Compt. rend. Acad. Sci. Paris, *180*, 1925, 1188 by Topley and Wilson, Princip. of Bact. and Immun., 2nd ed., 1936, 274. The latter organism is regarded as identical with *Haverhillia multiformis* Parker and Hudson, Amer. Jour. Path., *2*, 1926, 357 by Van Rooyen, Jour. Path. and Bact., *43*, 1936, 469; *Actinomyces muris* Topley and Wilson, *loc. cit.*) From a case of rat-bite fever.

Actinomyces musculorum Hertwig. (*Actinomyces musculorum suis* Duncker, Ztschr. f. Microskopie u. Fleischbeschau, *3*, 1884, No. 3; Hertwig, Arch. f. wissensch. u. prakt. Thierheilk., *12*, 1886, 365; *Oospora musculorum suis* Lehmann and Neumann, Bakt. Diag., 1 Aufl., *2*, 1896, 383.) Seen in calcareous deposits in the muscles of swine.

Actinomyces myricae Peklo. (Cent. f. Bakt., II Abt., *27*, 1910, 451.) From the roots of *Myrica*.

Actinomyces from Neddeni, Namyslowski. (Cent. f. Bakt., I Abt., Orig., *62*, 1912, 564.) From the human eyelid.

Actinomyces nigricans Killian and Fehér. (Ann. Inst. Past., *55*, 1935, 620.) From desert soil.

Actinomyces nigrificans (Krüger) Wollenweber. (*Oospora nigrificans* Krüger, Berichte der Versuchsstat. f. Zuckerrohrs, Kergok-Legal, 1890; Wollenweber, Arb. Forschungsinst. für Kartoffelbau, 1920, 16.) From potato scab.

Actinomyces nitrogenes Sartory, Sartory, Meyer and Walter. (Bull. Acad. Méd., Paris, *116*, 1936, 186; also Ann. Inst. Past., *58*, 1937, 684.) From sputum.

Actinomyces nivea. (Incorrectly attributed to Krainsky, 1914 by Chalmers and Christopherson, Ann. Trop. Med. and Parasit., *10*, 1916, 270.)

Actinomyces nondiastaticus Bergey et al. (Var. b, Bergey, Jour. Bact., *4*, 1919, 304; Bergey et al., Manual, 1st ed., 1923, 371.) From air.

Actinomyces ochraceus Neukirch. (Ueber Actinomyceten, Strassburg, 1902, 4.) From soil.

Actinomyces ochroleucus Neukrich. (Ueber Actinomyceten, Strassburg, 1902, 4.) From soil.

Actinomyces odorifera Koelz. (Inaug. Diss., Kiel, 1934; Le Lait, *16*, 1936, 154.)

Actinomyces oligocarbophilus Lantzsch. (Lantzsch, Cent. f. Bakt., II Abt., *57*, 1922, 309; *Proactinomyces oligocarbophilus* Krassilnikov, Bull. Acad. Sci., U. S. S. R., No. 1, 1938, 139.) Lantzsch regards this organism as identical with *Bacillus oligocarbophilus* Beijerinck and Van Delden, Cent. f. Bakt., II Abt., *10*, 1903, 33 (*Carboxydomonas oligocarbophila* Orla-Jensen, Cent. f. Bakt., II Abt., *22*, 1909, 311). Secures growth energy by oxidizing CO to CO_2. From soil. See Manual, 5th ed., 1939, 81 for a description of the bacillary stage of this organism. *Carboxyodomonas oligocarbophila* Orla-Jensen is the type species of the genus *Carboxydomonas* Orla-Jensen (*loc. cit.*).

Actinomyces orangico-niger. (Quoted from Lieske, Morphol. u. Biol. d. Strahlenpilze, Leipzig, 1921, 33.)

Actinomyces orangicus. (Quoted from Lieske, Morphol. u. Biol. d. Strahlenpilze, Leipzig, 1921, 33.)

Actinomyces pelogenes Sawjalow.

(Cent. f. Bakt., II Abt., *39*, 1913, 440.) From mud containing hydrogen sulfide.

Actinomyces pluricolor Terni. (*Streptothrix pluricolor* Fuchs; Terni, quoted from Gasperini, Cent. f. Bakt., *15*, 1894, 684; *Nocardia pluricolor* Chalmers and Christopherson, Ann. Trop. Med. and Parasit., *10*, 1916, 268.)

Actinomyces pluricolor diffundens Berestnew. (Inaug. Diss., Moskow, 1897; see Cent. f. Bakt., I Abt., *24*, 1898, 708.) From air.

Actinomyces praecox Millard and Burr. (Ann. Appl. Biol., *13*, 1926, 601.) From scab on potato.

Actinomyces praefecundus Millard and Burr. (Ann. Appl. Biol., *13*, 1926, 601.) From scab on potato and from soil.

Actinomyces protea (Schürmayer) Ford. (*Oospora proteus* and *Streptothrix proteus* Schürmayer, Cent. f. Bakt., I Abt., *27*, 1900, 58; Ford, *loc. cit.*, 208.) From an abscess of the foot.

Actinomyces pseudotuberculosae (Flexner) Brumpt. (*Streptothrix pseudotuberculosa* Flexner, Jour. Exp. Med., *3*, 1898, 438; Brumpt, Précis de Parasit., Paris, 4th ed., 1927, 1206.)

Actinomyces pseudotuberculosus Lehmann and Neumann. (*Actinomyces atypica pseudotuberkulosa* Hamm and Keller, Cent. f. Bakt., I Abt., Ref., *42*, 1909, 729; Lehmann and Neumann, Bakt. Diag., 5 Aufl., *2*, 1912, 621; *Nocardia pseudotuberculosis* de Mello and Fernandes, Mem. Asiatic Soc. Bengal, *7*, 1919, 110.)

Actinomyces purpureus Killian and Fehér. (Ann. Inst. Past., *55*, 1935, 620.) From desert soil.

Actinomyces putorii (Dick and Tunnicliff) Ford. (*Streptothrix putorii* Dick and Tunnicliff, Jour. Inf. Dis., *23*, 1918, 183; Ford, Textb. of Bact., 1927, 216.) From the blood of a patient bitten by a weasel.

Actinomyces pyogenes Lieske. (Eine neue Streptothrixspecies, Caminiti, Cent. f. Bakt., I Abt., Orig., *44*, 1907, 193; *Streptothrix pyogenes* Chalmers and Christopherson, Ann. Trop. Med. and Parasit., *10*, 1916, 270; Lieske, Morphol. u. Biol. d. Strahlenpilze, Leipzig, 1921, 32.) From air.

Actinomyces radiatus Namyslowski. (Namyslowski, Cent. f. Bakt., I Abt., Orig., *62*, 1912, 564; *Streptothrix radiatus* Chalmers and Christopherson, Ann. Trop. Med. and Parasit., *10*, 1916, 273; *Nocardia radiata* Vuillemin, Encyclopédie Mycologique, Paris, *2*, 1931, 126.) From an infection of the cornea of the human eye.

Actinomyces rosaceus. (Quoted from Lieske, Morphol. u. Biol. d. Strahlenpilze, Leipzig, 1921, 33.)

Actinomyces roseodiastaticus Duché. (Encyclopédie Mycologique, Paris, *6*, 1934, 329.)

Actinomyces roseus Namyslowski. (*Actinomyces sp.* Lowensteins Klin. Monatsbl. f. Augenheilk., *48*, 1910, 185; Namyslowski, Cent. f. Bakt., I Abt., Orig., *62*, 1912, 567; not *Actinomyces roseus* Krainsky, Cent. f. Bakt., II Abt., *41*, 1914, 662; *Discomyces roseus* Brumpt, Précis de Parasitol., Paris, 3rd ed., 1922, 981.)

Actinomyces saharae Killian and Fehér. (Ann. Inst. Past., *55*, 1935, 621.) From desert soil.

Actinomyces salmonicolor Millard and Burr. (Ann. Appl. Biol., *13*, 1926, 601.) From sour soil.

Actinomyces sampsonii Millard and Burr. (Ann. Appl. Biol., *13*, 1926, 601.) From scab on potato.

Actinomyces sanguinis Basu. (Ind. Jour. Med. Res., *25*, 1937, 325.) From the blood of a patient with bronchial pneumonia.

Actinomyces sanninii Ciferri. (Quoted from Baldacci, Boll. Sez. Ital. Soc. Internaz. di Microbiol., *9*, 1937, 140.)

Actinomyces setonii Millard and Burr. (Ann. Appl. Biol., *13*, 1926, 601.) From scab on potato.

Actinomyces spiralis Millard and Burr. (Ann. Appl. Biol., *13*, 1926, 601.) From decaying grass.

Actinomyces taraxeri cepapi (Schottmüller) Ford. (*Streptothrix taraxeri*

cepapi Schottmüller, Dermat. Wchnschr., *58*, 1914, Supplement, 77; Ford, *loc. cit.*, 196.) From a case resembling rat-bite fever following the bite of a South African squirrel (*Taraxerus cepapi*).

Actinomyces tenuis Millard and Burr. (Ann. Appl. Biol., *13*, 1926, 601.) From scab on potato.

Actinomyces thermodiastaticus Bergey et al. (Var. a, Bergey, Jour. Bact., *4*, 1919, 301; Bergey et al., Manual, 1st ed., 1923, 370.) From stomach contents of a rabbit.

Actinomyces thermotolerans Stadler. (Arch. f. Hyg., *33*, 1899, 40.) From milk and butter.

Actinomyces variabilis Cohn. (Cent. f. Bakt., I Abt., Orig., *70*, 1913, 301.) From pus in the bladder in a case of cystitis, and from the prostate.

Actinomyces verrucosus Nadson. (Nadson, Die Mikroorganismen als geologische Faktoren I. Petersburg, 1903; quoted from Dorff, Die Eisenorganismen, Pflanzenforschung, Jena, Heft 16, 1934, 43; not *Actinomyces verrucosus* Adler, 1901, see Nannizzi, in Pollacci, Tratt. Micopat. Umana, *4*, 1934, 46.) From sea mud. Deposits ferric hydroxide about the mycelial threads.

Actinomyces violaceus (Rossi Doria) Gasperini. (*Streptotrix violacea* Rossi Doria, Ann. d. Ist. d'Ig. sper. d. Univ. di Roma, *1*, 1891, 411; *Oospora violacea* Sauvageau and Radais, Ann. Inst. Past., *6*, 1892, 252; Gasperini, Cent. f. Bakt., *15*, 1894, 684; *Cladothrix violacea* Macé, Traité Pratique de Bact., 4th ed., 1901, 1075; *Nocardia violacea* Chalmers and Christopherson, Ann. Trop. Med. and Parasit., *10*, 1916, 270; *Discomyces violaceus* Brumpt, Précis de Parasitol., Paris, 3rd ed., 1922, 995.) From air and water.

Actinomyces viridis (Lombardo-Pellegrino) Sanfelice. (*Streptothrix viridis* Lombardo-Pellegrino, Riforma Med., *19*, 1903, 1065; also see Cent. f. Bakt., I Abt., Ref., *35*, 1904, 761; Sanfelice, Cent. f. Bakt., I Abt., Orig., *36*, 1904, 355.) From soil.

Actinomyces viridis Millard and Burr. (Millard and Burr, Ann. Appl. Biol., *13*, 1926, 601; not *Actinomyces viridis* Sanfelice, Cent. f. Bakt., I Abt., Orig., *36*, 1904, 355; not *Actinomyces viridis* Duché, Encyclopédie Mycologique, Paris, *6*, 1934, 311.) From scab on potato.

Actinomyces xanthostromus Wollenweber. (Arb. Forschungsinst. f. Kartoffelbau, 1920, 16.)

Actinomyces wedmorensis Millard and Burr. (Ann. Appl. Biol., *13*, 1926, 601.) From peat soil.

Asteroides lieskeyi Puntoni and Leonardi. (Boll. e Atti d. R. Accad. Med. di Roma, *61*, 1935, 94.) A renaming of *Actinomyces lieskey*, a culture whose source was unknown. This may possibly be the same as *Actinomyces lieskei* Duché (see *Streptomyces lieskei*).

Cladothrix odorifera Rullmann. (Rullmann, Inaug. Diss., Munich, 1895; see Cent. f. Bakt., I Abt., *17*, 1895, 884 and Cent. f. Bakt., II Abt., *2*, 1896, 116; *Oospora odorifera* Lehmann and Neumann, Bakt. Diag., 1 Aufl., *2*, 1896, 392; *Actinomyces odorifer* Lachner-Sandoval, Ueber Strahlenpilze, 1898, 65; *Streptothrix odorifera* Foulerton and Jones, Trans. Path. Soc. London, *53*, 1902, 112; *Nocardia odorifera* Castellani and Chalmers, Man. Trop. Med., 2nd ed., 1913, 818.) From sputum in a case of chronic bronchitis.

Cladothrix placoides Kligler. (*Leptothrix placoides alba* Dobrzyniecki, Cent. f. Bakt., I Abt., *21*, 1897, 225; Kligler, Jour. Allied Dental Soc., *10*, 1915, 141, 282 and 445; *Leptotrichia placoides* Bergey et al., Manual, 3rd ed., 1930, 458.) From a tooth canal. For a description of this species see Manual, 5th ed., 1939, 829. The description indicates that this organism belongs to *Nocardia* or *Streptomyces*.

Coccobacillus pseudo - actinomycosis polymorphus Berestneff. (Berestneff, 1898, quoted from Chalmers and Christopherson, Ann. Trop. Med. and Parasit., *10*, 1916, 273.)

Cohnistreptothrix americana Chalmers and Christopherson. (*Streptothrix sp.*

Bloomfield and Bayne-Jones, Johns Hopkins Hosp. Bull. 26, 1915, 230; Chalmers and Christopherson, Ann. Trop. Med. and Parasit., *10*, 1916, 273; *Actinomyces americanus* Dodge, Medical Mycology, St. Louis, 1935, 716.) From a liver abscess.

Cohnistreptothrix misri Carpano. (Riv. di Parasit., No. 2, 1937, 107.) From human dermatosis in Egypt.

Cohnistreptothrix silberschmidtii Chalmers and Christopherson. (Streptothrix, Silberschmidt, Cent. f. Bakt., I Abt., *27*, 1900, 486; Chalmers and Christopherson, Ann. Trop. Med. and Parasit., *10*, 1916, 273; *Nocardia silberschmidti* Froilano de Mello and Fernandes, Mem. Asiatic Soc. Bengal, *7*, 1919, 111; *Actinomyces silberschmidti* Dodge, Medical Mycology, St. Louis, 1935, 711.) From cases of dacryocystitis.

Discomyces decussatus Langeron and Chevallier. (Langeron and Chevallier, Compt. rend. Soc. Biol., *72*, 1912, 1030; *Nocardia decussata* Castellani and Chalmers, Man. Trop. Med., 2nd ed., 1913, 817; *Oospora decussata* Sartory, Champ. Paras. Homme et Anim., 1923, 825; *Actinomyces decussatus* Brumpt, Précis de Parasitol., 4th ed., 1927, 1206.) From dry, scaly lesions. Not considered pathogenic.

Nocardia chalmersi de Mello and Fernandes. (De Mello and Fernandes, Mem. Asiatic Soc. Bengal, *7*, 1919, 130; *Actinomyces chalmersi* Dodge, Medical Mycology, St. Louis, 1935, 734.) From the saliva of a horse.

Nocardia christophersoni de Mello and Fernandes. (De Mello and Fernandes, Mem. Asiatic Soc. Bengal, *7*, 1919, 130; *Actinomyces christophersoni* Dodge, Medical Mycology, St. Louis, 1935, 723.) From the air.

Nocardia citrea Chalmers and Christopherson. (Ann. Trop. Med. and Parasit., *10*, 1916, 270.) A blanket name proposed to include *Actinomyces griseoflavus* Krainsky, *Actinomyces flavus* Krainsky, *Streptothrix flava* Sanfelice and *Streptothrix flava* Bruns.

Nocardia cruoris Macfie and Ingram. (Macfie and Ingram, Ann. Trop. Med. and Parasit., *15*, 1921, 283; *Discomyces cruoris* Brumpt, Précis de Parasitol., Paris, 3rd ed., 1922, 984; *Oospora cruoris* Sartory, Champ. Paras. Homme et Anim., 1923, 809; *Actinomyces cruoris* Brumpt, *ibid.*, 4th ed., 1927, 1195.) From blood.

Nocardia dichotoma (Macé) Chalmers and Christopherson. (*Cladothrix dichotoma* Macé, Compt. rend. Acad. Sci. Paris, *6*, 1888, 1622; not *Cladothrix dichotoma* Cohn, Beitr. z. Biol. d. Pflanzen *1*, Heft 3, 1875, 185; Chalmers and Christopherson, Ann. Trop. Med. and Parasit., *10*, 1916, 270.)

Nocardia ferruginea Trevisan. (Bakterium bei Chorea St. Viti, Naunyn, Mittheil. aus der Med. Klinik zu Königsberg, 1888, 292; Trevisan, I generi e le specie delle Batteriacee, 1889, 9; *Actinomyces ferrugineus* Gasperini, Cent. f. Bakt., *15*, 1894, 684.) From pia mater in a case of St. Vitis' dance.

Nocardia garteni (Brumpt) Castellani and Chalmers. (*Cladothrix liquefaciens No. 2*, Garten, Deutsche Ztschr. f. Chirurg., *41*, 1895, 482; *Discomyces garteni* Brumpt, Précis de Parasitol., Paris, 1st ed., 1910, 860; Castellani and Chalmers, Man. Trop. Med., 2nd ed., 1913, 818; *Oospora garteni* Sartory, Champ. Paras. Homme et Anim., 1923, 778; *Actinomyces garteni* Brumpt, *loc. cit.*, 4th ed., 1927, 1191; *Actinomyces liquefaciens* Ford, Textb. of Bact., 1927, 202.) From cases of human actinomycosis.

Nocardia goensis de Mello and Fernandes. (De Mello and Fernandes, Mem. Asiatic Soc. Bengal, *7*, 1919, 130; *Actinomyces goensis* Dodge, Medical Mycology, St. Louis, 1935, 723.) From lesions of vitiligo. Saprophytic.

Nocardia liguire Urizer. (Urizer, 1904; *Actinomyces liguire* Nannizzi, in Pollacci, Tratt. Micopat. Umana, *4*, 1934, 49.)

Nocardia liquefaciens (Hesse) Castel-

lani and Chalmers. (*Cladothrix liquefaciens* Hesse, Deutsche Ztschr. f. Chirurg., *41*, 1895, 432; *Discomyces liquefaciens* Brumpt, Précis de Parasit., Paris, 1st ed., 1910, 860; Castellani and Chalmers, Man. Trop. Med., 2nd ed., 1913, 818; *Streptothrix liquefaciens* Chalmers and Christopherson, Ann. Trop. Med. and Parasit., *10*, 1916, 233, 265; *Oospora liquefaciens* Sartory, Champ. Paras. Homme et Anim., 1923, 778; *Actinomyces liquefaciens* Brumpt, *loc. cit.*, 4th ed., 1927, 1192.) From an inguinal abscess.

Nocardia microparva Chalmers and Christopherson. (Ann. Trop. Med. and Parasit., *10*, 1916, 268.) Listed as synonymous with *Actinomyces microparva* Krainsky, 1914 which may be intended for *Actinomyces microflavus* Krainsky, Cent. f. Bakt., II Abt., *41*, 1914, 662.

Nocardia orangica (Berestneff) Chalmers and Christopherson. (*Streptothrix orangica* Berestneff, Inaug. Diss., Moscow, 1897, quoted from Chalmers and Christopherson, Ann. Trop. Med. and Parasit., *10*, 1916, 271; Chalmers and Christopherson, *idem.*)

Nocardia rogersi de Mello. (*Nocardia* (*Cohnistreptothrix*) *rogersi* de Mello, A Med. Contemp., 1919; *Discomyces rogersi* Neveu-Lemaire, Précis Parasitol. Hum., 5th ed., 1921, 44; *Actinomyces rogersii* Brumpt, Précis de Parasitol., 4th ed., 1927, 1206.) From sputum.

Nocardia rubea Chalmers and Christopherson. (Ann. Trop. Med. and Parasit., *10*, 1916, 271.) *Nomen nudum.* According to Dodge (Medical Mycology, St. Louis, 1935, 765), this is a synonym of *Oospora rubra* Wilbert, Recueil Hyg. Méd. Vét. Militaire, 1908.

Nocardia saprophytica Chalmers and Christopherson. (*Streptothrix leucea saprophytica* Foulerton, 1902, quoted from Chalmers and Christopherson, Ann. Trop. Med. and Parasit., *10*, 1916, 270; Chalmers and Christopherson, *idem.*)

Nocardia urinaria Pijper. (Pijper, 1918, quoted from Castellani and Chalmers, Man. Trop. Med., 3rd ed., 1919, 1057; *Actinomyces urinarius* Nannizzi, in Pollacci, Tratt. Micopat. Umana, *4*, 1934, 50.)

Oospora hoffmanni (Gruber) Sauvageau and Radais. (*Mikromyces hofmanni* (sic) Gruber, Trans. Int. Congr. Hyg. Derm., VI, *2*, 1891–1892, 65 and Arch. f. Hyg., *16*, 1893, 35; Sauvageau and Radais, Ann. Inst. Past., *6*, 1892, 251; *Actinomyces hoffmanni* Gasperini, Cent. f. Bakt., *15*, 1894, 684; *Streptothrix hofmanni* Kruse, in Flügge, Die Mikroorganismen, 3 Aufl., *2*, 1896, 62; *Cladothrix hoffmanni* Macé, Traité Pratique de Bact., 4th ed., 1901, 1081; *Nocardia hoffmanni* Chalmers and Christopherson, Ann. Trop. Med. and Parasit., *10*, 1916, 268.) From a sample of vaccine.

Oospora spumalis Sartory. (Sartory, in Sartory and Bailly, Mycoses pulmonaires, 1923, 318; *Actinomyces spumalis* Dodge, Medical Mycology, St. Louis, 1935, 751.) From human sputum.

Streptothrix aaser Johan-Olsen. (Inaug. Diss., Christiania, 1893, 91; quoted from Neukirch, Ueber Actinomyceten, Strassburg, 1902, 69.)

Streptothrix alpha Price-Jones. (Price-Jones, 1900; quoted from Chalmers and Christopherson, Ann. Trop. Med. and Parasit., *10*, 1916, 270.) Considered synonymous with *Streptothrix alba* (Rossi Doria).

Streptothrix aquatilis Johan-Olsen. (Inaug. Diss., 1893, 93; quoted from Johan-Olsen, Cent. f. Bakt., II Abt., *3*, 1897, 279.)

Streptothrix beta Price-Jones. (Price-Jones, 1900; quoted from Chalmers and Christopherson, Ann. Trop. Med. and Parasit., *10*, 1916, 270; *Nocardia beta* Chalmers and Christopherson, *idem.*)

Streptothrix chondri Johan-Olsen. (Inaug. Diss., 1893, 95; quoted from Johan-Olsen, Cent. f. Bakt., II Abt., *3*, 1897, 278.)

Streptothrix enteritidis Pottien. (Quoted from Sanfelice, Cent. f. Bakt., I Abt., Orig., *36*, 1904, 355.)

Streptothrix foersteri Gasperini. (Gasperini, Annales de Micrographie, *2*, 1890, 462; not *Streptothrix foersteri* Cohn, Beitr. z. Biol. d. Pflanzen, *1*, Heft 3, 1875, 196; *Actinomyces saprophyticus* Gasperini, Ann. d. Ist. d'Ig. sper. d. Univ. Roma, *2*, 1892, 226; *Actinomyces saprophyticus* var. *cromogenus* Gasperini, *ibid.*, 229.) From air.

Streptothrix gelatinosus Johan-Olsen. (Cent. f. Bakt., II Abt., *3*, 1897, 279.)

Streptothrix humifica Johan - Olsen. (Cent. f. Bakt., II Abt., *3*, 1897, 278.)

Streptothrix lemani Johan-Olsen. (Inaug. Diss., 1893, 96; quoted from Johan-Olsen, Cent. f. Bakt., II Abt., *3*, 1897, 279.)

Streptothrix necrophora Wilhelm. (Monats. f. prakt. Tierheilk., *14*, 1902, 193.) See page 578.

Streptothrix leucea Foulerton. (In Allbutt and Rolleston, Syst. of Med., *2*, 1912, 310.)

Streptothrix melanotica Price-Jones. (On the General Characteristics and Pathogenic Action of the Genus *Streptothrix*, 1901; also see Foulerton, in Allbutt and Rolleston, Syst. of Med., *2*, 1912, 304.)

Streptothrix oidieformis Johan-Olsen. (Inaug. Diss., 1893, 96; quoted from Neukirch, Ueber Actinomyceten, Strassburg, 1902, 69.)

Streptothrix spirilloides Johan-Olsen. (Inaug. Diss., 1893, 96; quoted from Neukirch, Ueber Actinomyceten, Strassburg, 1902, 69.)

Streptothrix tartari Sanfelice. (Cent. f. Bakt., I Abt., Orig., *36*, 1904, 355.)

Streptothrix wallemia Johan-Olsen. (Inaug. Diss., 1893, 96; quoted from Neukirch, Ueber Actinomyceten, Strassburg, 1902, 69.)

Streptothrix zopfi Casagrandi. (Quoted from Caminiti, Cent. f. Bakt., I Abt., Orig., *44*, 1907, 198.)

Drechsler (Botan. Gazette, *67*, 1919, 65 and 147) described eighteen morphological types of *Actinomyces* (*Streptomyces*). The relationships of these types to species previously described in the literature are not explained except in four instances. Actinomyces III is regarded as *Actinomyces lavendulae* Waksman and Curtis; Actinomyces X is regarded as *Streptothrix alba* Rossi Doria (possibly *Actinomyces griseus* Krainsky); Actinomyces XII is regarded as *Actinomyces aureus* Waksman and Curtis; and Actinomyces XVII is *Actinomyces scabies* Güssow.

Genus II. Micromonospora *Ørskov.*

(Ørskov, Investigations into the morphology of the ray fungi. Copenhagen, 1923, 147; includes *Thermoactinomyces* Tsilinsky, Ann. Inst. Past., *13*, 1899, 501; *ibid.*, *17*, 1903, 206.)

Well developed, fine, non-septate mycelium, 0.3 to 0.6 micron in diameter. Grow well into the substrate. Not forming at any time a true aerial mycelium. Multiply by means of conidia, produced singly at end of special conidiophores, on surface of substrate mycelium. Conidiophores short and either simple, branched or produced in clusters. Strongly proteolytic and diastatic. Many are thermophilic and can grow at 65°C. Usually saprophytes. These organisms occur mostly in hot composted manure, dust, soil and in lake bottoms.

The type species is *Micromonospora chalcea* (Foulerton) Ørskov.

Key to the species of genus Micromonospora (*Ørskov Group III*).

I. Vigorously growing organisms, typically with copious spore formation on glucose-asparagine-agar.
   A. Vegetative mycelium pale pink to deep orange, no typical soluble pigment.
      1. *Micromonospora chalcea.*
   B. Vegetative mycelium orange changing to brownish-black, brown soluble pigment.
      2. *Micromonospora fusca.*

II. Slowly and feebly growing organisms, with scant spore formation on glucose-asparagine-agar, no soluble pigment.
   A. Vegetative mycelium pale pink to pale orange.
      3. *Micromonospora parva.*
   B. Vegetative mycelium yellow to orange-red.
      4. *Micromonospora globosa.*
   C. Vegetative mycelium blue.
      5. *Micromonospora vulgaris.*

NOTE: This genus could be subdivided on the basis of the relations of the organisms to temperature, since it includes a number of thermophilic forms which grow readily at 55° to 65°C, mesophilic forms having their optimum temperature at 30°C, and organisms growing at low temperatures in lakes. Each of these can be divided into 3 groups, based on the structure of the spore-bearing hyphae. Among the thermophilic forms, only representatives of the first group have so far been isolated in pure culture although the existence of the other two groups has definitely been demonstrated in microscopic preparations. These are:

Group 1. Simple spore-bearing hyphae.
Group 2. Branching spore-bearing hyphae.
Group 3. Spore-bearing hyphae in clusters.

1. **Micromonospora chalcea** (Foulerton) Ørskov. (*Streptothrix chalcea* Foulerton, Lancet, *1*, 1905, 1200; *Nocardia chalcea* Chalmers and Christopherson, Ann. Trop. Med. and Parasit., *10*, 1916, 268; Ørskov, Thesis, Copenhagen, 1923, 156; *Actinomyces chalcea* Ford, Textb. of Bact., 1927, 221.) From Greek *chalceus*, bronze.

Description from Jensen, Proc. Linn. Soc. New So. Wales, *57*, 1932, 173.

Formation of a unicellular mycelium which forms distally placed, singly situated spores. No aerial hyphae. No sur-

face growth in liquid medium. The organism resists desiccation for at least 8 months. Comparison between the power of resistance of the mycelium and the spores, respectively, will no doubt present great difficulty, because it is almost impossible to ensure that the two constituents are actually detached. Otherwise, the mycelium is but slightly capable of germinating, which may be ascertained by inoculating a water agar plate liberally with a mixture of mycelial threads and spores. While practically all the spores germinate, the mycelial threads were never found to form new colonies.

Vegetative mycelium on glucose-asparagine-agar: Heavy, compact, raised, pale pink to deep orange, not spreading much into the medium. Spore-layer well developed, moist and glistening, brownish-black to greenish-black, this color sometimes spreading through the whole mass of growth.

Gelatin is liquefied.

Grows in liquid media as small firm orange granules or flakes.

Milk is digested with a faintly acid reaction, mostly after a previous coagulation.

Many strains invert sucrose.

Some strains produce nitrites from nitrates.

Starch is hydrolyzed.

Most strains decompose cellulose.

Proteolytic action seems stronger in this than in the other species of this genus.

Optimum temperature for growth 30° to 35°C. Thermal death point of mycelium, 70°C in 2 to 5 minutes. Spores resist 80°C for 1 to 5 minutes.

Habitat: Soil, lake mud and other substrates. In addition to the above references, see Erikson (Jour. Bact., *41*, 1941, 299) and Umbreit and McCoy (A Symposium on Hydrobiology, Univ. of Wisconsin Press, 1941, 106–114).

2. **Micromonospora fusca** Jensen. (Proc. Linn. Soc. New So. Wales, *57*, 1932, 178.) From Latin *fuscus*, dark.

Vegetative mycelium on glucose-asparagine-agar heavy, compact, orange, rapidly changing to deep brown and nearly black; spore-layer moist, glistening, grayish- to brownish-black. Deep brown soluble pigment.

Gelatin is liquefied.

Grows in liquid media as small brown granules and flakes.

Milk is slowly digested; no coagulation.

Sucrose is inverted.

Reduction of nitrates, positive or negative.

Cellulose is attacked to a slight extent.

Starch is hydrolyzed.

Habitat: Soil.

3. **Micromonospora parva** Jensen. (Proc. Linn. Soc. New So. Wales, *57*, 1932, 177.) From Latin *parvus*, small.

Scant growth on glucose-asparagine-agar; vegetative mycelium thin, spreading widely into the agar, almost colorless to pale pink or orange. Sporulation scant, giving rise to thin grayish, moist crusts on the surface.

Gelatin is liquefied.

Milk is left unchanged; or coagulated, slowly redissolved with faintly acid reaction.

Sucrose not inverted.

Nitrates not reduced.

Cellulose not decomposed.

Starch is hydrolyzed.

Habitat: Soil.

4. **Micromonospora globosa** Krassilnikov. (Ray Fungi and Related Organisms. Izd. Acad. Nauk, Moskow, 1938, 134; Microbiology, U. S. S. R., *8*, 1939, 179.) From Latin *globosus*, spherical.

A fine (0.5 to 0.8 micron in diameter) monopodially branching mycelium. This mycelium breaks soon into separate pieces of varying length and irregular outline. Conidia are formed at the ends of short branches, one on each. Individual branches with conidia resemble grape vines. The conidia are spherical, 1.0 to 1.3 microns; they arise by the

swelling of the branch tips. The swellings become round, acquire the shape of spheres, which, as the formation of the conidia proceeds, are divided from the branch by a transverse septum.

Gelatin is liquefied.

Colonies: Rugose, at first very compact, later acquire a pasty consistency, and their bond with the medium becomes not so fast. The color of the cultures varies from light yellow to orange-red. During fruit-bearing the colonies are covered with a brownish-black tarnish of conidia.

In meat-peptone broth, ammonia is produced.

Milk: Coagulation; peptonization.

Nitrites are produced from nitrates.

Sucrose is inverted.

Cellulose not decomposed.

Starch is hydrolyzed.

Habitat: Soil.

5. **Micromonospora vulgaris** (Tsilinsky) Waksman, Umbreit and Gordon. (Thermophile *Cladothrix*, Kedzior, Arch. Hyg., *27*, 1896, 328; *Thermoactinomyces vulgaris* Tsilinsky, Ann. Inst. Past., *13*, 1899, 501; *Actinomyces monosporus* Schütze, Arch. f. Hyg., *67*, 1908, 50 (*Nocardia monospora* Chalmers and Christopherson, Ann. Trop. Med. and Parasit., *10*, 1916, 271); *Actinomyces glaucus* Lehmann and Schütze, in Lehmann and Neumann, Bakt. Diag., 5 Aufl., *2*, 1912, 641 (*Nocardia glauca* Chalmers and Christopherson, *loc. cit.*); *Micromonospora coerulea* Jensen, Proc. Linn. Soc. New So. Wales, *57*, 1932, 177; Waksman, Umbreit and Gordon, Soil Sci., *47*, 1939, 51.) From Latin *vulgaris*, common.

Morphologically the development of this organism is entirely comparable to that of the mesophilic form described by Jensen. The young mycelium shows slightly more branching than that produced by species of *Streptomyces*. Spores are borne at the end of short branches from which they are easily broken. The aerial mycelium, though present, is usually rudimentary, rarely exhibiting the tangled network of strands typical of species of *Streptomyces*. Thermophilic strains of *Micromonospora vulgaris* differ thus from the mesophilic forms, which show no trace of aerial mycelium. Fragmentation has not been seen in slide cultures of the organism thus far isolated, but it was found to occur in smear preparation.

According to Jensen, the mesophilic strains grow slowly on glucose-asparagine-agar; vegetative mycelium dense, dark greenish-blue, with a hard and glossy surface. Sporulation very scant. The surface sometimes shows a thin white veil resembling aerial mycelium, but without aerial spores.

Gelatin: Liquefaction.

Good growth on beef-peptone agar, potato, milk, beef-peptone broth, etc. Grows in liquid media as fairly large, firm, round, white to pink granules (Jensen). Usually a white, powdery, thin aerial mycelium is produced which is hardly raised above the surface. No soluble pigment is formed.

Czapek's agar: Growth white, powdery, slightly raised.

Broth: A tough white pellicle and in many instances a considerable number of ball-like colonies at the bottom of the tube. No turbidity.

Milk: Coagulated and digested.

Nitrites not produced from nitrates.

Sucrose not inverted.

Cellulose not decomposed.

Starch is hydrolyzed.

Optimum temperature of thermophilic forms 57°C. Growth range 48° to 68°C.

Habitat: Straw, soil, high temperature composts.

Appendix: The following anaerobic species has been described:

Micromonospora propionici Hungate. (Abst. in Jour. Bact., *48*, 1944, 380 and 499; Jour. Bact., *51*, 1946, 51.) From the alimentary tract of the wood-eating termite (*Amitermes minimus*). Ferments glucose or cellulose to form acetic and propionic acids and CO_2. Obligate anaerobe.

ORDER III. CHLAMYDOBACTERIALES BUCHANAN.

(Jour. Bact., *2*, 1917, 162.)

Filamentous, colorless, alga-like bacteria. May or may not be ensheathed. They may be unbranched or may show false branching. False branching arises from a lateral displacement of the cells of the filament within the sheath which gives rise to a new filament, so that the sheath is branched while the filaments are separate. The sheath may be composed entirely of iron hydroxide, or of an organic matrix impregnated with iron, or may be entirely organic. The filaments themselves may show motility by a gliding movement like that found in the blue-green algae (*Oscillatoriaceae*). Conidia and motile flagellate swarm cells may be developed, but never endospores. Fresh water and marine forms.

Key to the families of order **Chlamydobacteriales.***

I. Alga-like filaments which do not contain sulfur globules. False branching may occur.
   A. Usually free floating filaments. Motile swarm cells may be formed.
      Family I. *Chlamydobacteriaceae*, p. 981.
   B. Attached filaments which show a differentiation of base and tip. Non-motile conidia formed in the swollen tips of the filaments.
      Family II. *Crenothrichaceae*, p. 987.

II. Alga-like, unbranching filaments which may contain sulfur globules when growing in the presence of sulfides. Filaments may be motile by a creeping or sliding movement along a solid substrate.
      Family III. *Beggiatoaceae*, p. 988.

FAMILY I. CHLAMYDOBACTERIACEAE MIGULA.**

(Arb. Bakt. Inst. Hochschule, Karlsruhe, *1*, 1894, 237.)

Filamentous bacteria which frequently show false branching. Sheaths may or may not be impregnated with ferric hydroxide. Cells divide only transversely. Swarm cells, it developed, are usually motile by means of flagella. Usually found in fresh water.

Key to the genera of family **Chlamydobacteriaceae.**

I. Showing typical false branching.
   A. Sheaths entirely organic, not impregnated with ferric hydroxide.
      Genus I. *Sphaerotilus*, p. 982.
   B. Sheaths impregnated with ferric hydroxide.
      Genus II. *Clonothrix*, p. 983.

II. Unbranched or rarely showing false branching.
   A. Sheaths or holdfasts impregnated with ferric hydroxide.
      Genus III. *Leptothrix*, p. 983.

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* In Appendix I, p. 996, will be found a group of non-filamentous, non-sheath-forming, colorless sulfur bacteria, as the family *Achromatiaceae*. Their true relationships are as yet obscure, and they have been attached as an Appendix to the *Chlamydobacteriales* largely on account of the similarity of their metabolism to that of the *Beggiatoaceae*.

** Completely revised by Prof. A. T. Henrici, University of Minnesota, Minneapolis, Minnesota, December, 1938; further revision by Prof. Robert S. Breed, New York State Experiment Station, Geneva, New York, July, 1946.

Genus I. Sphaerotilus *Kützing.*

(Kützing, Linnaea, *8*, 1833, 385; *Cladothrix* Cohn, Beitr. z. Biol. d. Pflanz., *1*, Heft 3, 1875, 185.) From Greek *sphaera*, sphere.

Attached, colorless threads, showing false branching, though this may be rare in some species. Filaments consist of rod-shaped or ellipsoidal cells, surrounded by a firm sheath. Multiplication occurs both by non-motile conidia and by motile swarm cells, the latter with lophotrichous flagella.

The type species is *Sphaerotilus natans* Kützing.

1. **Sphaerotilus natans** Kützing. (Kützing, Linnaea, *8*, 1833, 385; not *Sphaerotilus natans* Sack, Cent. f. Bakt., II Abt., *65*, 1925, 116; *Cladothrix natans* Migula, in Engler and Prantl, Die natürl. Pflanzenfam. *1*, 1a, 1895, 46.) From Latin *natans*, swimming.

Cells cylindrical, surrounded by a sheath which is slimy in character, 2 to 3 microns in diameter. False branching rare.

Multiplication occurs through the formation of conidia within the sheath of the vegetative cells, from which they swarm out at one end, swim about for a time, then attach themselves to objects and develop into delicate filaments.

Gelatin rapidly liquefied, requires organic nitrogen, does not grow in the ordinary peptone solution, grows best with low concentrations of meat extract (Zikes, Cent. f. Bakt., II Abt., *43*, 1915, 529).

The culture cultivated and described as *Sphaerotilus natans* by Sack (Cent. f. Bakt., II Abt., *65*, 1925, 116) was identified as *Bacillus mycoides* by Haag (*ibid.*, *69*, 1926, 4).

Source: Originally found in polluted waters. May become a real nuisance in sewage purification plants of the activated sludge type (Lackey and Wattie, U. S. Pub. Health Ser., Pub. Health Repts., *55*, 1940, 975) and in streams polluted with sulfite liquor from pulp and paper mills (Lackey, Mimeographed Rept. U. S. Pub. Health Ser., 1941).

Habitat: Stagnant and running water, especially sewage polluted streams.

2. **Sphaerotilus dichotomus** (Cohn) Migula. (*Cladothrix dichotoma* Cohn, Beitr. z. Biol. d. Pflanz., *1*, Heft 3, 1875, 185; Migula, Syst. d. Bakt., *2*, 1900, 1033; *Sphaerotilus natans* var. *cladothrix* Butcher, Trans. Brit. Myc. Soc., *17*, 1932, 112.) From Greek *dichotomos*, cut in two parts, forked.

The identity of this species as distinct from *Sphaerotilus natans* has been questioned. Cohn's description applied to filaments 0.3 micron in diameter, while all later authors have applied the name to a much larger organism (2 to 4 microns in diameter).

Zikes (Cent. f. Bakt., II Abt., *43*, 1915, 529) gives the following differential characters: Cells smaller than *Sphaerotilus natans*, 1.5 to 2.5 microns; false branching constant; grows best in high concentrations of meat extract; will grow in ordinary peptone solutions; can utilize inorganic nitrogen; liquefies gelatin slowly.

Source: Found by Cohn in water containing *Myconostoc*.

Habitat: Comparatively unpolluted fresh water capable of sustaining algae.

3. **Sphaerotilus fluitans** (Migula) Schikora. (*Streptothrix fluitans* Migula, in Engler and Prantl, Die natürl. Pflanzenfam., *1*, 1a, 1895, 38; Schikora, Ztschr. f. Fischerei, *7*, 1899, 1-28; *Chlamydothrix fluitans* Migula, Syst. d. Bakt., *2*, 1900, 1033; *Leptothrix fluitans* Chester, Man. Determ. Bact., 1901, 370.) From Latin *fluitans*, flowing, floating.

Very thin attached filaments surrounded by a soft sheath, from which almost spherical conidia issue, usually attaching themselves to the exterior of the sheath, where they multiply.

Habitat: Swamp water or sewage polluted waters.

Appendix: Additional species have been described as belonging in this genus. Those described by Ravenel have generally been overlooked although he was one of the earliest workers to culture these organisms. The list follows:

Cladothrix fungiformis Ravenel. (Mem. Nat. Acad. Sci., *8*, 1896, 19.) From deep virgin soil.

Cladothrix intestinalis Ravenel (*loc. cit.*, 18). From virgin soil.

Cladothrix non-liquefaciens Ravenel (*loc. cit.*, 16). From deep made soil.

Cladothrix profundus Ravenel (*loc. cit.*, 17). From deep made soil.

Cladothrix ramosa Gasperini. (Atti d. Soc. toscana d'Ig., *2*, 1912, 000.) From water.

Cladothrix reticularis Naumann. (Kungl. Svenska Vetenskapsakad. Handl., I, *62*, Part 4, 1921, 44; *Sphaerotilus reticularis* Cataldi, Thesis, Univ. Buenos Aires, 1939, 55.) From Aneboda region, Sweden.

Sphaerotilus roseus Zopf. (Beiträge z. Physiol. u. Morph. nieder. Organismen, 1892, 32.) From water.

Genus II. **Clonothrix** *Roze.*

(Jour. d. Bot., *10*, 1896, 325.) From Greek *klon*, a twig and *thrix*, hair.

Attached filaments showing false branching as in *Sphaerotilus*. Sheaths organic, encrusted with iron or manganese, broader at the base and tapering toward the tip. Cells colorless, cylindrical. Reproduction by spherical conidia formed in chains by transverse fission of cells; conidia formation acropetal, limited to short branches of the younger portion of the filaments.

The type species is *Clonothrix fusca* Roze.

1. **Clonothrix fusca** Roze. (Roze, Jour. d. Bot., *10*, 1896, 325; *Clonothrix fusca* Schorler, Cent. f. Bakt., II Abt., *12*, 1904, 689; *Crenothrix fusca* Dorff, Die Eisenorganismen, Pflanzenforschung, Heft 16, 1934, 41.) From Latin *fuscus*, brown.

Cells cylindrical with rounded ends, 2 by 10 microns, becoming larger toward the base and smaller toward the tips of the filaments.

Sheaths 7 microns at the base to 2 microns at the tips.

Conidia about 2 microns in diameter.

This organism was described by Roze as a blue-green alga, but subsequent observers have failed to find pigment. It was described independently by Schorler who gave it the same name. Cholodny considered it identical with *Crenothrix polyspora* but Kolk (Amer. Jour. Bot., *25*, 1938, 11) has clearly differentiated these species.

Habitat: Waterworks and pipes.

Appendix: Apparently the following species resemble *Clonothrix fusca*:

Clonothrix tenuis Kolkwitz. (Kolkwitz, Schizomycetes in Kryptogamenflora der Mark Brandenburg, *5*, 1915, 144; *Crenothrix tenuis* Dorff, Die Eisenorganismen, Pflanzenforschung, Heft *16*, 1934, 42.) From the settling basin of a sewage plant near Berlin. Dorff thinks this may have been a growth form of *Crenothrix fusca* Dorff.

Mycothrix abundans Naumann. (Kungl. Svenska Vetenskapsakad. Handl. I, *62*, 1921, Part 4, 44.) From the Aneboda region, Sweden. The type species of the genus *Mycothrix.*

Mycothrix clonotricoides Naumann (*loc. cit.*, 54). From the Aneboda region, Sweden.

Genus III. **Leptothrix** *Kützing.*

(Kützing, Phycologia Generalis, 1843, 198; not *Leptotrichia* Trevisan, Reale Ist. Lombardo di Sci. e Lettere, Ser. 2, *12*, 1879, 138; *Detoniella* DeToni and Trevisan, in

Saccardo, Sylloge Fungorum, *6*, 1889, 929; *Chlamydothrix* Migula, Syst. d. Bakt., *2*, 1900, 1030; *Conidiothrix* Benecke, Bau u. Leben d. Bakt., 1912, 489; *Megalothrix* Schwers, Cent. f. Bakt., II Abt., *33*, 1912, 273; *Syncrotis* Enderlein, Sitzber. Gesell. Naturf. Freunde, Berlin, 1917, 312.) From Greek *leptos*, small and *thrix*, hair.

Filaments of cylindrical colorless cells, with a sheath at first thin and colorless, later thicker, yellow or brown, encrusted with ferric hydroxide. The oxide may be dissolved by dilute acid, whereupon the inner cells show up well. Multiplication is by division and abstraction of cells and by motile cylindrical swarmers. False branching may occur.

The type species is *Leptothrix ochracea* Kützing.

Key to the species of genus **Leptothrix.**

I. Filaments not spirally twisted.
  A. Free swimming, not attached.
    1. Sheath homogeneous, cylindrical.
      1. *Leptothrix ochracea.*
    2. Sheath composed of a bundle of fine parallel filaments.
      2. *Leptothrix trichogenes.*
  B. Attached to a substrate by a holdfast.
    1. Arising singly, each filament from its own holdfast.
      a. Filaments show false branching.
        3. *Leptothrix discophora.*
      aa. Filaments unbranched.
        4. *Leptothrix sideropous.*
    2. Numerous filaments arising from a common holdfast.
      a. Filaments large, uniform in diameter.
        5. *Leptothrix lopholea.*
      aa. Filaments smaller, tapering toward the tip.
        6. *Leptothrix echinata.*
II. Filaments spirally twisted.
  A. Epiphytic, growing twisted around filamentous algae.
    7. *Leptothrix epiphytica.*
  B. Not epiphytic.
    8. *Leptothrix pseudovacuolata.*

1. **Leptothrix ochracea** Kützing. (Kützing, Phycologia Generalis, 1843, 198; *Lyngbya ochracea* Thuret, Ann. Sci. Nat. Bot., VI, *1*, 1875, 279; *Beggiatoa ochracea* Gasperini, Ann. d'Igiene Sper., *2*, 1912, 000; *Chlamydothrix ochracea* Migula, Syst. d. Bakt., *2*, 1900, 1031.) From Latin *ochra*, yellow.

Long filaments, free-floating, never attached to a substrate, never branching. Filaments 1 micron in thickness, composed of rod-like colorless cells, surrounded in young filaments by a delicate sheath which later becomes yellow to brown in color.

Sheath homogeneous, completely dissolving in dilute hydrochloric acid.

When the sheath becomes very thick, the filaments creep out of the sheath and secrete a new one, so that many empty sheaths are found. Polar flagellate, motile, swarm-cells have been observed.

Habitat: Iron-bearing waters.

2. **Leptothrix trichogenes** Cholodny. (Cholodny, Cent. f. Bakt., II Abt., *61*, 1924, 292; *Toxothrix ferruginea* Molisch, Die Eisenbakterien in Japan, Sc. Report Tohoku J. Univ., 4 Ser. Biol., *1*, 1925,

13.) From Greek *thrix*, hair and *geno*, producing.

Long, slender, articulated filaments, free-floating, never branched. Filaments 0.5 micron in thickness, composed of rod-like colorless cells.

Filaments surrounded by a fine sheath. This sheath ruptures longitudinally and rolls up as a fine hair-like body at one side of the filament. This process continually repeated leads to the development of a thick sheath composed of numerous hair-like bodies arranged in parallel bundles, which are easily separated from the filament. The sheath is completely dissolved in dilute hydrochloric acid.

Mode of reproduction is unknown.

Habitat: Iron-bearing waters.

3. **Leptothrix discophora** (Schwers) Dorff. (*Megalothrix discophora* Schwers, Cent. f. Bakt., II Abt., *33*, 1912, 273; *Leptothrix crassa* Cholodny, Cent. f. Bakt., II Abt., *61*, 1924, 292; *Chlamydothrix discophora* Naumann, Ber. d. Deutsch. Bot. Ges., *46*, 1928, 141; Dorff, Die Eisenorganismen, Pflanzenforschung, Heft 16, 1934, 31.) From Latin *discus*, disk and Greek *phorous*, to bear.

Long, slender, articulated filaments composed of elements of varying length showing false branching (Cholodny, *loc. cit.*, 297). Usually attached to a submerged substrate but may be free-floating.

Filaments surrounded by a heavy sheath, thick (10 to 15 microns) at the base, tapering toward the free tip, heavily impregnated with ferric hydroxide.

Reproduction by motile swarm cells liberated from the tip, and also by the emergence of the filament from the sheath, with subsequent breaking up into individual non-motile cells (conidia).

Habitat: Water.

4. **Leptothrix sideropous** (Molisch) Cholodny. (*Chlamydothrix sideropous* Molisch, Die Eisenbakterien, 1910, 14; *Gallionella sideropous* Naumann, Kungl. Svenska Vetenskapsakad., *62*, 1921, 33; Cholodny, Die Eisenbakterien, Pflanzenforschung, Heft *4*, 1926, 25.) From Greek *sideros*, iron.

Short, unbranched filaments composed of rod-shaped cells of varying length, 0.6 micron in diameter.

Sheath very thin, colorless, giving an iron reaction only at the base of the filament. Attached by a broad holdfast which gives a marked iron reaction.

Habitat: Found in water, growing on submerged surfaces.

5. **Leptothrix lopholea** Dorff. (Die Eisenorganismen, Pflanzenforschung, Heft 16, 1934, 33.) From Greek *lophos*, crest, tuft.

Short, slender unbranched filaments, uniform in diameter, attached to a substrate, 5 to 13 filaments arising from a common holdfast. Filaments 20 to 33 microns long, cells 0.5 by 1.0 to 1.3 microns.

Sheaths composed of ferric hydroxide dissolve completely in dilute hydrochloric acid.

Filaments creep out of the sheath as in *Leptothrix ochracea*.

Habitat: Water.

6. **Leptothrix echinata** Beger. (Cent. f. Bakt., II Abt., *92*, 1935, 401.) From Latin *echinatus*, bristled.

Similar to the preceding species, but occurring in larger colonies, 20 to 50 filaments arising from a common holdfast. Filaments are shorter (9 to 10 microns).

Sheath is thicker at the base and tapers toward the free tip of the filaments, which are slightly spiral. The sheath contains an organic matrix visible after treatment in dilute hydrochloric acid.

Habitat: Found in water, especially in manganese-bearing waters.

7. **Leptothrix epiphytica** (Migula) Chester. (*Streptothrix epiphytica* Migula,

in Engler and Prantl, Die natürl. Pflanzenfam., *1*, 1a, 1895, 38; *Lyngbya epiphytica* Hieronymus, in Kirchner, *ibid.*, 67; Chester, Manual Determ. Bact., 1901, 370; *Leptothrix volubilis* Cholodny, Cent. f. Bakt., II Abt., *61*, 1924, 292; *Chlamydothrix epiphytica* Naumann, Ber. d. Deutsch. Bot. Ges., *46*, 1928, 141.) From M.L. *epiphyticus*, epiphytic.

Long cylindrical unbranched filaments growing spirally around filaments of *Tolypothrix*, *Oedogonium*, etc. Cells rod-shaped, 1 by 2 microns.

Sheaths cylindrical, encrusted with iron.

Cells may leave the sheaths as in *Leptothrix ochracea*.

Habitat: Water.

8. **Leptothrix pseudovacuolata** (Perfiliev) Dorff. (*Spirothrix pseudovacuolata* Perfiliev, Verh. d. Int. Verein. f. theor. u. angew. Limnologie, 1925, Stuttgart, 1927; Dorff, Die Eisenorganismen, Pflanzenforschung, Heft 16, 1934, 36.) From Greek, having false vacuoles.

Filaments 85 to 250 microns in length, unbranched, spirally wound, occasionally straight. Strongly encrusted with ferric hydroxide. Spirals 20 to 24 microns from crest to crest.

Cells rounded at the ends, thin-walled, granular, 1.7 to 2.8 by 3.5 to 30 microns.

Apparently heterotrophic.

Habitat: Found in bottom muds of deep lakes with very low oxygen content.

Appendix: The following simple, filamentous organisms have also been placed in the genus *Leptothrix* or appear to belong here:

Chlamydothrix thermalis Molisch. (Die Eisenbakterien in Japan. Sc. Report Tohoku J. Univ., 4 Ser. Biol., *1*, 1923, 135; *Leptothrix thermalis* Dorff, Die Eisenorganismen, Pflanzenforschung, Heft 16, 1934, 38.) From hot springs in Japan.

Leptothrix hyalina (Migula) Bergey et al. (*Streptothrix hyalina* Migula, in Engler and Prantl, Die natürl. Pflanzenfam., *1*, 1a, 1895, 38; *Chlamydothrix hyalina* Migula, Syst. d. Bakt., *2*, 1900, 1003; Bergey et al., Manual, 1st ed., 1923, 391.) From swamp water.

Leptothrix major Dorff. (Die Eisenorganismen, Pflanzenforschung, Heft 16, 1934, 35.) From Spree River water near Berlin.

Leptothrix winogradskii Cataldi. (Thesis, Univ. Buenos Aires, 1939, 64.) From water.

Lieskeella bifida Perfiliev. (Perfiliev, Verh. d. internat. Vereinigung f. theoret. u. angew. Limnologie, 1925, Stuttgart, 1927; quoted from Dorff, Die Eisenorganismen, Pflanzenforschung, Heft 16, 1934, 27; also designated *Lieskeella bifilaris* by Perfiliev.) From iron bearing water. Shows gliding movements similar to blue-green algae. The type species of the genus *Lieskeella* Perfiliev.

Sideromyces glomerata Naumann. (Quoted from Dorff, Die Eisenorganismen, Pflanzenforschungen, Heft 16, 1934, 27.) From swamps in the Aneboda region of Sweden. This is the type species of the genus *Sideromyces* syn. *Mycogallionella* Naumann.

Sphaerothrix latens Perfiliev. (Perfiliev, Verh. d. internat. Vereinigung f. theoret. u. angew. Limnologie, 1925, Stuttgart, 1927; quoted from Dorff, Die Eisenorganismen, Pflanzenforschung, Heft 16, 1934, 29.) From a peat bog in a small pond near Leningrad. This is the type species of the genus *Sphaerothrix* Perfiliev. Grows in disks showing a concentric structure.

FAMILY II. CRENOTHRICHACEAE HANSGIRG.*

(Österr. Bot. Ztschr., *36*, 1888, 228.)

Filaments not branched, attached to a firm substrate, showing differentiation of base and tip. Sheaths plainly visible, thin and colorless at the tip, thick and encrusted with iron at the base. Cells cylindrical to spherical, dividing in three planes to produce the spherical non-motile conidia.

Genus I. Crenothrix *Cohn.*

(Cohn, Beitr. z. Biol. d. Pflanz., *1*, Heft 1, 1870, 108; *Phragmidiothrix* Engler, Verh. Bot. Ver. Brandenb., *24*, 1882, 19.) From Greek *crenos*, spring and *thrix*, hair.

Characters as for the family.

The type species is *Crenothrix polyspora* Cohn.

1. **Crenothrix polyspora** Cohn. (Beitr. z. Biol. d. Pflanz., *1*, Heft 1, 1870, 108; *Hypheothrix kuehniana* Rabenhorst, Flora europ. algarum, Sect. II, 88; *Leptothrix kuehniana* Rabenhorst, Algen Sachsens, No. 284; *Crenothrix kuehniana* Zopf, Zur Morphologie der Spaltpilzen, 1882, 36; *Crenothrix manganifera* Jackson, Hyg. Rund., *14*, 1904, 19.) From Greek, many spores.

Long, articulated filaments, unbranched, enclosed in a sheath which becomes expanded toward the tip. The sheath is composed of organic matter encrusted with iron. Filaments, including the sheath, measure 2 to 9 microns in diameter.

Vegetative cells vary markedly in length from long cylindrical to short ovoid forms.

Conidia, spherical, 1 to 2 microns in diameter, are liberated from the expanded tips of the sheaths. They are non-motile.

Cultivation: Has not been grown on artificial media in pure culture.

Conidia may germinate upon the exterior of the sheath from which they have been liberated, giving rise to new filaments attached to the surface of the older one, presenting a simulation of false branching.

Cholodny believed *Clonothrix fusca* to be identical with *Crenothrix polyspora*. However, *Clonothrix fusca* shows genuine false branching and produces conidia by fission in only one plane, so that the filaments taper toward the tip instead of expanding (see Kolk, Amer. Jour. Bot., *25*, 1938, 11) for a clear cut differentiation of these two species.

Source: This organism is wide-spread in water pipes, drain pipes and springs where the water contains iron. It frequently fills pipes under such circumstances and causes a real nuisance. Found by Cohn in samples of water from springs in the neighborhood of Breslau, Germany.

Habitat: In stagnant and running waters containing organic matter and iron salts, growing as thick brownish or greenish masses.

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* Completely revised by Prof. A. T. Henrici, University of Minnesota, Minneapolis, Minnesota, December, 1938; further revision by Prof. Robert S. Breed, New York State Experiment Station Geneva, New York, July, 1946.

FAMILY III. BEGGIATOACEAE MIGULA.*

(Arb. Bakt. Inst. Karlsruhe, *1*, 1894, 238: in part, *Leuco-Thiobacteria* Bavendamm, Die farblosen and roten Schwefelbakterien, Pflanzenforschung, Heft *2*, 1924, 102.)

Filamentous organisms, composed of chains of cells. Individual cells generally not visible without staining. Structure very similar to that of *Oscillatoriaceae*, but devoid of chlorophyll and phycocyanin. When growing in the presence of hydrogen sulfide, the filaments contain sulfur globules. Special reproductive structures unknown.

In proposing the family *Beggiatoaceae* for the two genera of this subgroup known in 1894, Migula remarked that "it would be best to combine them with the *Oscillatoriaceae* and classify them among the Schizophyta" (Arb. Bakt. Inst. Karlsruhe, *1*, 1894, 238). The same authority has stated: "Also in view of their internal structure the species of *Beggiatoa* are so similar to those in the genus *Oscillaria* that they can hardly be separated generically" (in Engler and Prantl, Die natürl. Pflanzenfam., *1*, 1a, 1895, 41).

Since then, the close relationship between the filamentous, colorless sulfur bacteria and the blue-green algae of the family *Oscillatoriaceae* has become increasingly clear. A particularly important line of evidence is supplied by the discovery of sulfur bacteria paralleling each of the major genera of the *Oscillatoriaceae*. The family *Beggiatoaceae* Migula is retained for these filamentous sulfur bacteria. Taxonomically they could readily be classified as colorless members of the class *Schizophyceae*.

Key to the genera of family **Beggiatoaceae.**

I. Filaments non-motile. Grow attached by means of holdfast at base.
Genus I. *Thiothrix*, p. 988.

II. Filaments motile, like *Oscillatoria*, by creeping or sliding movements along a solid substrate. Not attached.
- A. Occurring singly, not embedded in a common slime-sheath.
  1. Filaments straight or bent, but not permanently coiled.
  Genus II. *Beggiatoa*, p. 990.
  2. Filaments coiled or spirally wound.
  Genus III. *Thiospirillopsis*, p. 993.
- B. Occurring in bundles, embedded in a common slime-sheath.
  Genus IV. *Thioploca*, p. 993.

Genus I. **Thiothrix** *Winogradsky.*

(Beitr. z. Morph. u. Physiol. d. Bakt., I, Schwefelbacterien, Leipsig, 1888, 39.) From Greek *theion*, sulfur, and *thrix*, hair.

Filaments non-motile, segmented, with a delicate sheath, and differentiated into base and tip. Grow attached at base to solid objects by means of gelatinous holdfast. Reproduction by transverse fission of the segments, and by rod-shaped so-called conidia, probably arising by the apical segments becoming free. Temporarily, the conidia show creeping motility, settle on solid objects, and grow out into new filaments.

The type species is *Thiothrix nivea* (Rabenhorst) Winogradsky.

The following key to the species of the genus *Thiothrix* is based upon the diameter

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* Completely revised by Prof. C. B. Van Niel, Hopkins Marine Station, Pacific Grove, California, January, 1944.

of the filaments and their habitat, the only criteria used by previous authors for the differentiation of the seven published species. The validity of these distinguishing characteristics is, however, doubtful because their constancy has not been sufficiently established; so far the morphology of the *Thiothrix* species has not been studied in pure cultures.

Key to the species of genus **Thiothrix.**

I. Found in fresh water environments.
  A. Diameter of filaments about 2 (1.4 to 3.0) microns.
    1. *Thiothrix nivea.*
  B. Diameter of filaments about 1 micron.
    2. *Thiothrix tenuis.*
  C. Diameter of filaments less than 0.5 micron.
    3. *Thiothrix tenuissima.*
II. Found in marine environments.
  A. Diameter of filaments averages about 20 microns (actual range 15 to 30 microns).
    4. *Thiothrix voukii.*
  B. Diameter of filaments about 4 (4.4 to 6.6) microns. Segments about 25 microns long.
    5. *Thiothrix longiarticulata.*
  C. Diameter of filaments about 3 (1.8 to 5) microns. Segments about 1 micron long.
    6. *Thiothrix annulata.*
  D. Diameter of filaments about 1 (0.8 to 1.3) micron.
    7. *Thiothrix marina.*

1. **Thiothrix nivea** (Rabenhorst) Winogradsky. (*Beggiatoa nivea* Rabenhorst, Flora europaea algarum, *2*, 1865, 94; *Leptotrichia nivea* De Toni and Trevisan, in Saccardo, Sylloge Fungorum, *8*, 1889, 934; *Symphyothrix nivea* Wartman and Schenk, Schweiz. Kryptogamenflora; Winogradsky, Beitr. z. Morph. u. Physiol. d. Bact., I, Schwefelbacterien, 1888, 39.) From Latin *niveus*, snowy.

Filaments with a thin sheath, diameter 2.0 to 3.0 microns at base, 1.7 microns in the middle, 1.4 to 1.5 microns at tip. As long as the filaments contain sulfur globules, segmentation is invisible; length of segments 4 to 15 microns, the longer ones usually near apex, the shorter ones near base.

Motile segments (so-called conidia) mostly single, 8 to 15 microns long, sometimes in short filaments of 2 to 4 cells and up to 40 microns long. These segments may settle and develop near the base of the mother filament or on a filament itself, forming verticillate structures. These have been described as *Thiothrix nivea* var. *verticillata* Miyoshi (Jour. Coll. Sci., Imp. Univ. Tokyo, *10*, 1897, 156).

Habitat: Fresh water environments where hydrogen sulfide is present (sulfur springs, stagnant pools, on submerged decaying vegetation, etc.).

2. **Thiothrix tenuis** Winogradsky. (*Beggiatoa alba* var. *uniserialis* Engler, Üb. die Pilz-Vegetation des weissen oder todten Grundes in der Kieler Bucht, 1883, 4; Winogradsky, Beitr. z. Morph. u. Physiol. d. Bact., I, Schwefelbacterien, 1888, 40.) From Latin *tenuis*, slender.

Filaments about 1.0 micron in diameter, of nearly uniform thickness. Often in dense, felted masses. Segments 4 to 5 microns long.

Habitat: Fresh water environments

where hydrogen sulfide occurs. According to Bavendamm (Die farblosen u. roten Schwefelbakt., Pflanzenforschung, Heft 2, 1924, 107) also found in sea water.

3. **Thiothrix tenuissima** Winogradsky. (Beitr. z. Morph. u. Physiol. d. Bact., I, Schwefelbacterien, 1888, 40; *Thiothrix minutissima* Uphof, Arch. f. Hydrobiol., *18*, 1927, 77.) From Latin *tenuis*, diminutive, very slender.

Filaments less than 0.5 micron in diameter, usually in dense masses.

Habitat: Fresh water environments where hydrogen sulfide occurs.

4. **Thiothrix voukii** Klas. (Arch. f. Protistenk., *88*, 1936, 123.) Named for Vouk, a Russian scientist.

Filaments 15 to 30, most frequently 17 microns in diameter, of rather uniform thickness. Segments visible without special treatment. Segments generally somewhat longer than wide, rarely square, occasionally barrel-shaped. Length of segments 15 to 30, mostly 19 to 23 microns. Motile segments not yet observed.

Apart from the lack of motility, this species closely resembles the motile *Beggiatoa mirabilis*.

Source: Found in effluent of sulfur springs at seashore near Split, Jugoslavia. So far reported only once.

Habitat: Marine environments containing hydrogen sulfide.

5. **Thiothrix longiarticulata** Klas. (Arch. f. Protistenk., *88*, 1936, 126.) From Latin *longus*, long and *articulatus*, jointed.

Filaments 3.3 to 6.6, most frequently 4.2 microns in diameter, of uniform thickness. Occur in dense, felted masses. Segments long, measuring 19 to 33, mostly 26 microns in length. Sulfur droplets usually absent in the proximity of cross-walls. Motile segments not yet reported.

Source: Found in effluent of sulfur springs at seashore near Split, Jugoslavia. So far reported only once.

Habitat: Marine environments containing hydrogen sulfide.

6. **Thiothrix annulata** Molisch. (Cent. f. Bakt., II Abt., *33*, 1912, 58.) From Latin *annulatus*, ringed.

Filaments 3 to 4, occasionally up to 5 microns in diameter, thinner at base (2 microns) and at tip (1.8 microns). Segments only about 1 micron in length. Often found with narrow bands which are free of sulfur, thus giving a ringed appearance to the filaments. Old filaments may show spacial thickening and distortion, but this is not characteristic for the species.

Habitat: Marine environments containing hydrogen sulfide; frequently on decaying algae.

7. **Thiothrix marina** Molisch. (Cent. f. Bakt., II Abt., *33*, 1912, 58.) From Latin *marinus*, pertaining to the sea.

Filaments about 1 (0.8 to 1.3) micron in diameter, of rather uniform thickness. Usually in felted masses.

Resembles *Thiothrix tenuis*. Since the latter has been reported from marine environments (Bavendamm, Die farblosen u. roten Schwefelbakterien, Pflanzenforschung, Heft 2, 1924, 107), *Thiothrix marina* may not be an independent species, but identical with *Thiothrix tenuis*.

Habitat: Marine (?) environments containing hydrogen sulfide; frequently on decaying algae.

Genus II. **Beggiatoa** *Trevisan.*

(Prospetto della Flora Euganea, 1842, 56.) Named for the Vicenza physician, F. S. Beggiato.

Filamentous, motile, segmented organisms, occurring singly or in white to creamy felted masses in which the separate filaments retain their individuality. Not at-

tached. Existence of a sheath not definitely established. Movements of the filaments dependent upon a solid substratum over which they slide in the same manner as species of *Oscillatoria*. Sliding movements often accompanied by rotation of filaments around long axis. Reproduction by transverse fission of segments; the filaments may also break up into smaller units, each continuing a separate existence. The latter mode of multiplication corresponds to that by means of the so-called motile conidia or segments in *Thiothrix*.

The type species is *Beggiatoa alba* (Vaucher) Trevisan.

In this genus, also, the species so far described are differentiated on the basis of dimensions. The range of sizes for separate species appears, in most cases, quite arbitrary, especially in view of the existence of practically all intermediate stages. Since the smaller forms have been found both in fresh water and marine environments (Bavendamm, Die farblosen u. roten Schwefelbakterien, Pflanzenforschung, Heft 2, 1924, 104), the previously described *Beggiatoa marina* has been omitted as a separate species. Pure culture studies may establish more staisfactory methods of differentiation and a better understanding of speciation.

Key to the species of genus **Beggiatoa.**

I. Diameter of filaments greater than 25 microns.
    1. *Beggiatoa gigantea.*
II. Diameter of filaments less than 25 microns.
    A. Diameter of filaments greater than 15 microns.
        2. *Beggiatoa mirabilis.*
    B. Diameter of filaments less than 15 microns.
        1. Diameter of filaments greater than 5 microns.
            3. *Beggiatoa arachnoidea.*
        2. Diameter of filaments less than 5 microns.
            a. Diameter of filaments greater than 2.5 microns.
                4. *Beggiatoa alba.*
            aa. Diameter of filaments less than 2.5 microns.
                b. Diameter of filaments greater than 1 micron.
                    5. *Beggiatoa leptomitiformis.*
                bb. Diameter of filaments less than 1 micron.
                    6. *Beggiatoa minima.*

1. **Beggiatoa gigantea** Klas. (Arch. f. Mikrobiol., *8*, 1937, 318; includes the arge forms of *Beggiatoa mirabilis* Cohn, Hedwigia, *4*, 1865, 81.) From Greek *gigas*, giant.

Filaments 26.4 to 55, average 35 to 40 microns in diameter. Klas, in his diagnosis, gives 26.4 to 42.9 microns as dimensions. This would exclude the largest forms of *Beggiatoa mirabilis* described by Hinze (Ber. d. deut. bot. Ges., *19*, 1901, 369). Since the proposal of a separate species for such organisms appears at present unjustified, the maximum diameter has here been increased. Filaments clearly segmented; length of segments 5 to 13, average 8.5 microns. Terminal cells rounded or tapering.

When the filaments are in healthy condition they are of uniform width; bulging of the sides indicates unfavorable conditions.

Habitat: Apparently restricted to marine environments containing hydrogen sulfide. Frequent on decaying marine algae.

2. **Beggiatoa mirabilis** Cohn *emend.* Klas. (Cohn, Hedwigia, *4*, 1865, 81;

Klas, Arch. f. Mikrobiol., *8*, 1937, 318.) From Latin *mirabilis*, wonderful.

Filaments 15 to 21.5, average 17 microns in diameter. The so-defined species does not overlap with *Beggiatoa gigantea* according to Klas (*loc. cit.*). Segmentation usually observable without special treatment; segments 5 to 13, average 8.5 microns long. Terminal cells rounded or tapering, sometimes bent.

When the filaments are in healthy condition they are of uniform width; an unfavorable environment induces bulging of the sides.

Habitat: Apparently restricted to marine environments containing hydrogen sulfide. Common on decaying marine algae.

Uphof (Arch. f. Hydrobiol., *18*, 1927, 83) has created a species, *Beggiatoa maxima*, which on account of its diameter (10 to 20 microns) falls partly within the range of *Beggiatoa mirabilis*, partly within *Beggiatoa arachnoidea*. Since it was found in a fresh water environment, the habitat of *Beggiatoa mirabilis* may not be restricted to marine media.

3. **Beggiatoa arachnoidea** (Agardh) Rabenhorst. (*Oscillatoria arachnoidea* Agardh, Regensburger Flora, 1827, 634; Rabenhorst, Flora europaea algarum, 1865, 94; *Beggiatoa pellucida* Cohn, Hedwigia, *4*, 1865, 82; ? *Oscillatoria beggiatoides* Arzichowsky, Bull. Jard. Imp. Bot., St. Pétersb., *2*, 1902, 38, 47; includes the larger members of *Beggiatoa major* Winogradsky, Beitr. z. Morph. u. Physiol. d. Bact., I, Schwefelbacterien, 1888, 25; and the smaller ones of *Beggiatoa maxima* Uphof, Arch. f. Hydrobiol., *18*, 1927, 80.) From Greek, resembling a cobweb.

Filaments 5 to 14 microns in diameter. Segmentation generally observable only after special staining or removal of sulfur globules; segments 5 to 7 microns in length. Terminal cells rounded, often tapering. Filaments of uniform width.

Habitat: Both fresh water and marine environments containing hydrogen sulfide.

4. **Beggiatoa alba** (Vaucher) Trevisan. (*Oscillatoria alba* Vaucher, Histoire des Conferves d'eau douce, 1803, 198; *Beggiatoa punctata* Trevisan, Prospetto della Flora Euganea, 1842, 56; *Beggiatoa alba* var. *marina* Cohn, Hedwigia, *4*, 1865, 83; *Beggiatoa marina* Molisch, Cent. f. Bakt., II Abt., *33*, 1912, 58; in part, *Beggiatoa major* Winogradsky, Beitr. z. Morph. u. Physiol. d. Bact., I, Schwefelbacterien, 1888, 25.) From Latin *albus*, white.

This is the type species of the genus.

Filaments 2.5 to 5, most commonly 3 microns in diameter, of even width. Segmentation difficult to detect in filaments containing many sulfur globules; segments 3 to 9 microns long, shortly after division practically square. Terminal cells rounded.

Habitat: Both fresh water and marine environments containing hydrogen sulfide.

Distribution: Ubiquitous, and probably the most common of the filamentous sulfur bacteria.

5. **Beggiatoa leptomitiformis** (Meneghini) Trevisan. (*Oscillatoria leptomitiformis* Meneghini, Delle Alghe viventi nelle terme Euganee, 1844, 122; Trevisan, Prospetto della Flora Euganea, 1842, 56; *Beggiatoa media* Winogradsky, Beitr. z. Morph. u. Physiol. d. Bact., I, Schwefelbacterien, 1888, 25.) From Greek *leptos*, small and *mitos*, thread and Latin *forma*, shape.

Filaments 1 to 2.5 microns in diameter, of uniform width. Segmentation only observable after removal of sulfur globules; segments 4 to 8 microns in length. Terminal cells usually rounded.

Habitat: Fresh water and marine environments containing hydrogen sulfide.

6. **Beggiatoa minima** Winogradsky. (Winogradsky, Beitr. z. Morph. u. Physiol. d. Bacterien, I. Schwefelbacterien, 1888, 25; *Beggiatoa minor* Uphof, Arch. f. Hydrobiol., *18*, 1927, 79; not *Beggiatoa minima* Warming, Om Nogle ved Danmarks Kyster levende Bakterier, 1876, 52, which from the description is not a *Beggiatoa.*) From Latin *minimus*, least.

Filaments less than 1 micron in diameter, of uniform width. Normally appears unsegmented; length of segments about 1 micron.

Habitat: Fresh water and marine environments containing hydrogen sulfide.

Genus III. Thiospirillopsis *Uphof.*

(Arch. f. Hydrobiol., *18*, 1927, 81.) From Greek *theion*, sulfur M.L. *spirillum*, spirillum and Greek *opsis*, appearance.

Filamentous, colorless sulfur bacteria, segmented, and spirally wound. Exhibit creeping motility, combined with rotation, so that the filaments move forward with a corkscrew-like motion. The tips produce oscillating movements. Resembles *Spirulina* among the *Oscillatoriaceae.*

The type species is *Thiospirillopsis floridana* Uphof.

1. **Thiospirillopsis floridana** Uphof. (Arch. f. Hydrobiol., *18*, 1927, 83.) Named from Florida, the place where it was first found.

Filaments 2 to 3 microns in diameter. Segmentation difficult to observe without special precautions; segments about 3 to 5 microns long. The spiral windings are regular.

Source: Found in the sulfur spring water at Wekiwa Springs and Palm Springs, Florida. A very similar organism has been observed at Pacific Grove, California, in a marine aquarium where hydrogen sulfide had been generated by sulfate reduction. The genus *Thiospirillopsis* may, therefore, be more wide-spread than is generally believed.

Habitat: Probably widely distributed in water containing sulfur.

Genus IV. Thioploca *Lauterborn.*

(Ber. d. deut. botan. Ges., *25*, 1907, 238.) Name derived from Greek *theion*, sulfur, and *ploka*, braid.

Filaments of *Beggiatoa*-like appearance, but occurring in parallel or braided bundles, enclosed by a common wide slime-sheath. The latter is frequently incrusted on the outside with detritus. Within the sheath the individual filaments are motile in the manner of *Beggiatoa*; the filaments are segmented, the terminal segments often tapering.

Resembles closely the genera *Hydrocoleus* and *Microcoleus* among the *Oscillatoriaceae.*

It is doubtful whether the members of the genus *Thioploca* are true colorless sulfur bacteria; most investigators of these forms have reported a greenish-blue coloration of the filaments. Only the regular occurrence of sulfur droplets in filaments taken from their natural habitat stamps the organisms as sulfur bacteria. In view of the close relationship of the *Beggiatoaceae* to the blue-green *Oscillatoriaceae*, this is, however, a minor issue.

Four species have been described to date. Three correspond, with respect to the individual filaments, to *Beggiatoa arachnoidea*, *Beggiatoa alba*, and *Beggiatoa leptomitiformis* respectively; the fourth appears to be a combination of the first and third

species of *Beggiatoa* in a common sheath. This occurrence of two distinct species of *Beggiatoa* in a common sheath makes the genus a doubtful taxonomic entity.

The type species is *Thioploca schmidlei* Lauterborn.

Key to the species of genus **Thioploca.**

I. Filaments in a common sheath of fairly uniform diameter.
  A. Diameter of individual filaments 5 to 9 microns.
    1. *Thioploca schmidlei.*
  B. Diameter of individual filaments 2 to 5 microns.
    2. *Thioploca ingrica.*
  C. Diameter of individual filaments 1 to 2 microns.
    3. *Thioploca minima.*

II. Filaments in common sheath of greatly different diameter.
    4. *Thioploca mixta.*

1. **Thioploca schmidlei** Lauterborn. (Ber. d. deut. bot. Ges., *25*, 1907, 238.) Named for Mr. Schmidle.

Individual filaments in a common sheath 5 to 9 microns in diameter, clearly segmented. Segments 5 to 8 microns in length. Mucilaginous sheath 50 to 160 microns in diameter. Number of filaments embedded in one sheath variable.

Source: Various localities in Central Europe.

Habitat: So far reported only in fresh water mud, containing hydrogen sulfide and calcium carbonate.

2. **Thioploca ingrica** Wislouch. (Ber. d. deut. bot. Ges., *30*, 1912, 470.) From *Ingria*, an ancient district of Leningrad.

Individual filaments in common sheath 2 to 4.5 microns in diameter, clearly segmented. Segments 1.5 to 8 microns in length. Mucilaginous sheath up to 80 microns in diameter. Number of filaments in one sheath variable.

Source: Various localities in Central Europe.

Habitat: Found in fresh water and marine mud containing hydrogen sulfide.

3. **Thioploca minima** Koppe. (Arch. f. Hydrobiol., *14*, 1923, 630.) From Latin *minimus*, least.

Individual filaments in a common sheath 0.8 to 1.5 microns in diameter, segmentation generally observable only after removal of sulfur droplets. Segments 1 to 2 microns long. Mucilaginous sheath up to 30 microns in diameter. Number of filaments in one sheath variable.

Source: Various localities in Central Europe.

Habitat: Fresh water and marine mud containing hydrogen sulfide.

4. **Thioploca mixta** Koppe. (Arch. f. Hydrobiol., *14*, 1923, 630.) From Latin *mixtus*, mixed.

Individual filaments in a common sheath of two clearly different sizes, comprizing both filaments of 6 to 8 microns, and filaments of about 1 micron in diameter. The former are clearly segmented, with segments of 5 to 8 microns in length. In the latter segmentation is visible after removal of sulfur droplets; segments 1 to 2 microns long. Mucilaginous sheath usually about 50 microns thick. Number of filaments in one sheath variable.

Source: Reported so far only from Lake Constanza.

Habitat: Fresh water mud containing hydrogen sulfide.

Appendix: In addition to the above genera and species, a number of insufficiently characterized, filamentous sulfur bacteria which may be related to the

Beggiatoaceae have been described under various names as follows:

Conidiothrix sulphurea Petersen. (Dansk Botan. Arkiv., *1*, 1921, 1.)

Filamentous, nonmotile organisms, of uniform width, between 0.5 and 1 micron in diameter, covered on the outside with sulfur. Segmentation not reported. The outstanding characteristic of the genus *Conidiothrix* is the supposed multiplication of the filaments by means of conidia which arise by budding on the filament. Apart from this reported occurrence of a budding process, the description is similar to that of *Leptothrix sulphurea* and of *Thiothrix tenuis* and *Thiothrix tenuissima*. Since consecutive observations on growing organisms are lacking, it seems advisable to consider *Conidiothrix sulphurea* as probably identical with *Thiothrix tenuis* or *Thiothrix tenuissima*.

Leptothrix sulphurea Miyoshi. (Jour. Coll. Sci., Imp. Univ. Tokyo, Japan, *10*, 1897, 154.)

Filamentous, non-motile organisms, of uniform width, not exceeding 0.7 micron in diameter. The filaments are covered on the outside with a powdery deposit of elementary sulfur. Segmentation observable only after special staining; length of segments not published.

Found by Miyoshi in sulfur springs in Japan. Although not reported as containing sulfur globules inside the filaments, the description would closely fit *Thiothrix tenuis* or *Thiothrix tenuissima* Winogradsky. The latter have been observed in masses covered on the outside with elementary sulfur. Therefore, it seems likely that *Leptothrix sulphurea* is a synonym for *Thiothrix tenuis* or *Thiothrix tenuissima*.

Thionema vaginatum Kolkwitz. (Ber. d. deut. bot. Ges., *56*, 1938, 11.)

The type species of the genus *Thionema*.

Described as a filamentous, colorless sulfur bacterium, non-motile, attached in the manner of *Thiothrix*. Filaments 1.5 to 2 microns in diameter, segmented. Segments 2 to 5 microns long. Reproduction, as in the case of *Thiothrix*, by means of detached segments.

While this part of the description fits that of *Thiothrix nivea*, the new generic name was proposed on the basis of the occurrence of a distinct sheath, frequently impregnated with iron compounds. Since Winogradsky mentions the occurrence of a sheath also in *Thiothrix nivea*, it seems desirable to consider *Thionema vaginatum*, at least for the time being, as a probable synonym of *Thiothrix nivea*.

Source: Found on waterplants in the Teltow-Canal near Berlin, the water containing hydrogen sulfide and iron salts.

Thiosiphon adriaticum Klas. (Sitzungsber. Akad. d. Wissensch. Wien, Mathem.-naturw. Kl., I, *145*, 1936, 209.)

Described as a filamentous sulfur bacterium, non-motile, but without segmentation, hence tubular and unicellular. Multiplication by means of conidia arising from restriction of the apical part of the cell. Length of filament about 1 to 1.5 mm, width 17 to 53 microns, usually tapering towards apex. Conidia 13 to 30 microns by 30 to 50 microns.

The description is at variance with the appearance of the organism in the published photomicrograph in so far as the size of the conidia is concerned. From the photomicrograph this appears to be about 30 by 200 microns. The entire appearance is strongly reminiscent of that of *Beggiatoa mirabilis* (*Beggiatoa gigantea*) in certain cultures. The short conidia, described in the text, strikingly resemble species of *Achromatium*. Consecutive observations on growing cultures of *Thiosiphon* do not appear to

have been made. Since (a) the internal structure of the large *Beggiatoaceae* is easily damaged, (b) the segmentation in living individuals is difficult to observe when the filaments are filled with sulfur, (c) the presence of *Achromatium* in the locality from which *Thiosiphon* was collected is almost certain, and (d) the developmental cycle is merely a reconstruction of simultaneously observed elements, considerable doubt as to the validity of the genus appears justified.

* **Appendix I:** The group of large, unicellular, colorless sulfur bacteria is placed here as a single family, *Achromatiaceae* Massart as in previous editions of the MANUAL. It includes organisms which are similar in physiology to the *Beggiatoaceae*.

Massart (Rec. Inst. Bot. Univ. Bruxelles, *5*, 1902, 251) proposed the family *Achromatiaceae* for the bacteria described by Schewiakoff (Über einen neuen bacterienähnlichen Organismus des Süsswassers, Habilitationsschrift, Heidelberg, 1893) as *Achromatium oxaliferum*. The family diagnosis was modified by Nadson (Jour. Microbiol., St. Pétersb., *1*, 1914, 72) and by Nadson and Wislouch (Bull. Princip. Jard. Bot. Républ. Russe, *22*, 1923, 33) to include the genera *Thiophysa* and *Thiosphaerella*.

In this form, the family represents a homogeneous group of organisms, all characterized by a pronounced similarity in cell-shape, structure, method of reproduction and motility. They exhibit very slow, jerky and rotating movements, but are devoid of flagella or other visible organs of locomotion. They closely resemble the blue-green algae of the genus *Synechococcus*, even in size.

By including the genus *Thiospira* in the family *Achromatiaceae*, Buchanan (Jour. Bact., *3*, 1918, 462) modified the diagnosis to read:

Unicellular, large, motile (by means of flagella?). Cells containing granules of sulfur (or in one form possibly oxalate) but no bacteriopurpurin.

Thus was proposed a family in which the spiral sulfur bacteria, indubitably related to species of *Spirillum* among the *Eubacteriales*, were linked with the taxonomically obscure species included in *Achromatium* and *Thiophysa*. Four genera, *Achromatium*, *Thiophysa*, *Thiospira* and *Hillhousia* were recognized.

Bavendamm (Die farblosen und roten Schwefelbakterien, Pflanzenforschung, Heft 2, 1924, 109), following the same trend, also combined all non-filamentous forms of the colorless sulfur bacteria into a family *Achromatiaceae*, with the diagnosis: Cells free, motile. As he realized that *Hillhousia* should be regarded as a synonym of *Achromatium* and added the genus *Thiovulum* Hinze (Ber. d. deut. bot. Ges., *31*, 1913, 195), four genera were again included in the family. *Thiosphaerella* was added as an appendix to *Thiophysa*.

Thiovulum is morphologically similar to *Achromatium*, *Thiophysa*, and *Thiosphaerella* with respect to cell size and structure, but differs conspicuously in being actively and rapidly motile. The manner of locomotion suggests the presence of polarly inserted flagella. However, these have never been demonstrated convincingly.

While it is conceivable that a relationship exists between *Thiovulum* and the organisms of the *Achromatium* type, the combination of the representatives into one family should be regarded as tentative and open to question. There certainly is no justification at present for including the sulfur spirilla in this family. These are placed in this edition of the MANUAL in *Spirilleae* among the *Eubacteriales*.

* **Completely revised by Prof. C. B. Van Niel, Hopkins Marine Station, Pacific Grove, California, January, 1944.**

FAMILY A. ACHROMATIACEAE MASSART.

(Rec. Inst. Bot. Univ. Bruxelles, *5*, 1902, 251.)

Cells large, spherical to ovoid in shape, sometimes rod-shaped, may contain globules of sulfur and/or calcium carbonate crystals. Do not possess photosynthetic pigments. Fresh water and marine forms.

A satisfactory differentiation of the genera *Achromatium*, *Thiophysa*, and *Thiosphaerella* is at present well-nigh impossible. They have here been combined into a single genus, *Achromatium*.

Achromatium mobile Lauterborn (Verhandl. Natur-histor.-Mediz. Vereins Heidelberg, N.F., *13*, 1915, 413) is fundamentally different from the other members of the genus. It possesses a clearly visible polar flagellum, suggesting its close affinity with the *Pseudomonadaceae* among the *Eubacteriales*. Whether it is a true sulfur bacterium has not been established with certainty; this appears very doubtful in the case of the two similar forms described as *Pseudomonas bipunctata* and *Pseudomonas hyalina* by Gicklhorn (Cent. f. Bakt., II Abt., *50*, 1920, 425, 426). Utermöhl and Koppe (Verhandl. Intern. Ver. f. theoret. u. angew. Limnologie, 1913, 86 and Archiv f. Hydrobiol., Suppl. Bd. *5*, 1925, 234) have proposed the generic name *Macromonas* for this group. This has been adopted here.

All of the above mentioned organisms have so far been studied exclusively as found in their natural habitats. Pure culture studies are greatly needed. These may show that the peculiar calcium carbonate inclusions (not calcium oxalate as thought by Schewiakoff, nor calcium thiosulfate as believed by Hannevart) in *Achromatium oxaliferum* and in *Macromonas bipunctata* occur only under special environmental conditions.

Key to the genera of family **Achromatiaceae.**

I. Large, ovoid to spherical organisms, normally containing sulfur globules when found in the presence of hydrogen sulfide.
  A. Non-motile, or slowly, jerkily sliding across the substrate.
    Genus I. *Achromatium*, p. 997.
  B. Actively motile, independent of the substrate.
    Genus II. *Thiovulum*, p. 999.
II. Rod-shaped and curved organisms, motile by means of polar flagella.
  A. Bean-shaped to short rod-shaped organisms which may contain small sulfur globules, but are chiefly characterized by large, round spherules of calcium carbonate as cell inclusions. The polar flagellum is often visible in the larger forms without special staining.
    Genus III. *Macromonas*, p. 1000.

Genus I. **Achromatium** *Schewiakoff.*

(Schewiakoff, Üb. einen neuen bacterienähnlichen Organismus des Süsswassers, Habilitationsschr., Heidelberg, 1893; *Modderula* Frenzel, Biol. Centralbl., *17*, 1897, 801; *Hillhousia* West and Griffiths, Proc. Roy. Soc., B, *81*, 1909, 389). From Greek *a*, without and *chroma*, color.

Thiophysa Hinze (Ber. d. deut. bot. Ges., *21*, 1903, 309) and *Thiosphaerella* Nadson (Jour. Microbiol., St. Pétersb., *1*, 1914, 72) are also included in the genus as defined here.

Unicellular organisms with large cells, shortly cylindrical with hemispherical extremities, also ellipsoidal to spherical. Cells divide by a constriction in the

middle. Movements, if any, are of a slow, rolling, jerky type and are dependent upon the presence of a substrate. No special organs of locomotion are known. In their natural habitat, the cells contain sulfur droplets and sometimes additional inclusions, such as large spherules of calcium carbonate.

The type species is *Achromatium oxaliferum* Schewiakoff.

It is not easy as yet to determine whether several species should be recognized in this genus. There appears to be some justification for differentiating between the forms which contain the characteristic and conspicuous calcium carbonate inclusions and forms in which these large spherules are lacking. The former have been reported mostly from fresh or brackish water environments, while the characteristic habitat of the latter seems to be marine. It is, of course, probable that the internal deposition of calcium carbonate depends upon the composition of the environment, so that the distinction may prove arbitrary and non-specific.

Achromatium cells of widely different sizes have been described. Schewiakoff (Üb. einen neuen bacterienähnlichen Organismus des Süsswassers, Habilitationsschrift, Heidelberg, 1893) mentions a variation of 15 to 43 microns in length, and 9 to 22 microns in width for *Achromatium oxaliferum*. Larger cells have been observed by Warming (Videnskab. Meddel. naturhistor. Foren., Kjöbenhavn, 1875, No. 20–28, 360; size to 85 microns), and by Virieux (Ann. Sci. Natur., Sér. 9, *18*, 1913, 265; size to 95 microns in length).

Nadson (Bull. Jard. Imp. Botan., St. Pétersb., *13*, 1913, 106; Jour. Microb., St. Pétersb., *1*, 1914, 52) proposed the name *Achromatium gigas* for the larger organisms; also West and Griffiths (Ann. Bot., *27*, 1913, 83) created two species, *Hillhousia mirabilis*, with sizes of 42 to 86 microns long by 20 to 33 microns wide, and *Hillhousia palustris*, measuring on the average 14 by 25 microns, for the same group of sulfur bacteria.

However, Bersa (Sitzungsber. Akad. Wiss., Wien, Mathem.-naturw. Kl., I, *129*, 1920, 233) observed so many intermediate sizes that he recognized only a single species. Nadson and Wislouch (Bull. Princ. Jard. Botan., Républ. Russe, *22*, 1923, Suppl. 1, 33) arrived at the same conclusion, and this view is accepted here.

The marine *Achromatium* types which do not contain calcium carbonate crystals, also have been segregated into species on the basis of their size. Here again, there does not seem to be any valid reason for maintaining several species as there is a continuous series of intermediate forms.

Thus, the organisms previously described as *Achromatium oxaliferum*, *Achromatium gigas*, *Hillhousia mirabilis* and *Hillhousia palustris* are provisionally treated here as one species, while the marine counterpart, *Thiophysa volutans*, is combined with *Thiophysa macrophysa* and *Thiosphaerella amylifera*, all three being regarded as *Achromatium volutans*.

Key to the species of genus **Achromatium.**

I. Organisms characteristically containing calcium carbonate crystals in the form of highly refractile, large spherules. Occur mostly in fresh water and brackish muds.

1. *Achromatium oxaliferum*.

II. Organisms naturally occurring without such calcium carbonate inclusions. Found in marine mud.

2. *Achromatium volutans*.

1. **Achromatium oxaliferum** Schewiakoff. (Schewiakoff, Üb. einen neuen bacterienähnlichen Organismus des Süsswassers, Habilitationsschrift, Heidelberg, 1893; *Modderula hartwigi* Frenzel, Biol. Centralbl., *17*, 1897, 801; *Hillhousia mirabilis* West and Griffiths, Proc. Roy. Soc., B, *81*, 1909, 389; *Hillhousia palustris* West and Griffiths, Ann. Bot., *27*, 1913, 83; *Achromatium gigas* Nadson, Bull. Jard. Imp. Bot., St. Pétersb., *13*, 1913, 106). From Latin *oxalis*, intended to refer to the supposed presence of oxalate crystals and *fero*, to bear.

Unicellular organisms, varying in shape from spherical or ovoid to shortly cylindrical with hemispherical extremities. Division by constriction in the middle. Cells vary in size from spheres of about 7 microns or even less in diameter to giant forms 100 microns long by 35 microns wide. The extremes are connected by a continuous series of intermediate sizes.

Organisms may show motility of a jerky and rotating kind, always very slow, and dependent upon a substrate. Typical organs of locomotion absent.

Normally contain small sulfur globules, accompanied by much larger calcium carbonate crystals, the latter in the form of large highly refractile spherules. Under favorable environmental conditions these may disappear before the sulfur globules. Cells with calcium carbonate inclusions have a very high specific gravity. They are, therefore, found only in the bottom of pools, streams, etc., usually in the mud.

Strictly microaerophilic, and apparently require hydrogen sulfide.

Habitat: Fresh water and brackish mud containing hydrogen sulfide and calcium salts. According to Nadson and Wislouch (Bull. princip. Jard. bot., Républ. Russe, *22*, 1923, Suppl. 1, 33) also in marine mud.

2. **Achromatium volutans** (Hinze) *comb. nov.* (*Thiophysa volutans* Hinze, Ber. d. deut. bot. Ges., *21*, 1903, 309; *Thiophysa macrophysa* Nadson, Bull. Jard. Imp. Bot., St. Pétersb., *13*, 1913, 106 and Jour. Microb., St. Pétersb., *1*, 1914, 54; *Thiosphaerella amylifera* Nadson, Bull. Jard. Imp. Bot., St. Pétersb., *13*, 1913, 106 and Jour. Microb., St. Pétersb., *1*, 1914, 54.) From Latin *volutans*, rolling.

Unicellular organisms, spherical to ovoid in shape, dividing by constriction in the middle. Size variable, ranging from spheres about 5 microns in diameter to ovoids up to 40 microns in length.

Cells may show motility of a jerky and rotating kind, always very slow, and dependent upon a substrate. Typical organs of locomotion absent.

Normally contain sulfur globules, but lack large internal calcium carbonate deposits.

Microaerophilic, apparently requiring hydrogen sulfide.

Habitat: Marine mud containing hydrogen sulfide; decaying seaweeds.

Genus II. **Thiovulum** *Hinze.*

(Ber. d. deut. bot. Ges., *31*, 1913, 195.) From Greek *theion*, sulfur and Latin *ovum*, egg.

Unicellular organisms, round to ovoid. Cytoplasm often concentrated at one end of the cell, the remaining space being occupied by a large vacuole. Multiplication by constriction which, in late stages, merges into fission. Actively motile; movements accompanied by rapid rotation. Flagellation not definitely demonstrated, but type of locomotion suggests polar flagellation. Normally contain sulfur globules in the cytoplasm, hence, these are frequently concentrated at one end of the cell.

The type species is *Thiovulum majus* Hinze.

As in the case of *Achromatium*, it is difficult to establish distinct species. Those that have been described differ only in size, and the differences appear to be far from constant. For *Thiovulum* (*Monas*) *mülleri* (Warming) Lauterborn (Verhandl. Naturhist.-medizin. Vereins, Heidelberg, N. F., *13*, 1915, 414) the diameter is stated by Warming (Videnskab. Meddel. naturhistor. Foren., Kjöbenhavn, 1875, No. 20–28, 363), Hinze (Ber. d. deut. bot. Ges., *31*, 1913, 191) and Lauterborn (*loc. cit.*, 415) respectively to be 5.6 to 15, 13 to 15 and 5 to 13 microns. The ovoid cells of *Thiovulum majus* are noted as being 11 to 18 microns long and 9 to 17 microns wide, while *Thiovulum minus* comprises the smaller forms from 9.6 to 11 microns long by 7.2 to 9 microns wide. In view of the regular occurrence of all intermediate sizes it seems best to recognize only a single species at present.

1. **Thiovulum majus** Hinze. (Hinze, Ber. d. deut. bot. Ges., *31*, 1913, 195; including *Thiovulum minus* Hinze, *idem.*; *Monas mulleri* Warming, Videnskab. Meddel. naturhistor. Foren., Kjöbenhavn, 1875, No. 20–28, 363; *Achromatium mulleri* Migula, Syst. d. Bakt. *2*, 1900, 1038; *Thiovulum mulleri* Lauterborn, Verhandl. Naturhist.-medizin. Vereins, Heidelberg, N.F., *13*, 1915, 414.) From Latin *major*, large.

Unicellular organisms, spherical to ovoid. Cytoplasm often concentrated at one end of the cell, the remainder being occupied by a vacuole. Multiplication by constriction which, in late stages, merges into fission. Size of cells, 5 to 20 microns in diameter.

The most characteristic feature is its motility; it is the only one of the spherical to ovoid, colorless sulfur bacteria capable of rapid movement. Flagellation has not been definitively demonstrated, but the type of locomotion suggests the presence of polar flagella.

Normally contains sulfur droplets in cytoplasm, frequently concentrated at one end of cell.

Microaerophilic; apparently requires hydrogen sulfide.

Habitat: In sulfide-containing water, usually accumulating near the surface. Often in cultures of decaying algae. Both in fresh water and marine environments.

Genus III. Macromonas *Utermöhl and Koppe.*

(Verhandl. Intern. Ver. f. Theoret. u. angew. Limnologie, 1923, 86.) From Latin *macro*, large and *monas*, a unit or cell.

Colorless, cylindrical to bean-shaped bacteria, actively motile by means of a single polar flagellum. Multiplication by constriction (fission). Chiefly characterized by the occurrence of calcium carbonate inclusions in the form of large spherules. In their natural habitat they may also contain small sulfur globules.

The type species is *Macromonas mobilis* (Lauterborn) Utermöhl and Koppe.

Two species have primarily been distinguished on the basis of cell size. Whether this is sufficiently constant to serve as a specific character has not been definitely established. From studies still limited in scope and extent on the organisms in their natural habitat, it appears at present that the two species should be maintained, at least provisionally. It is possible, however, that further observations, especially with cultures under different environmental conditions, will show the occurrence of intermediate types and of a greater range of variation in size of pure cultures than what has previously been reported.

Key to the species of genus **Macromonas.**

I. Cells measuring 12 microns or more in length and 8 microns or more in width.
1. *Macromonas mobilis.*

II. Cells measuring less than 12 microns in length and 5 microns or less in width.
2. *Macromonas bipunctata.*

1. **Macromonas mobilis** (Lauterborn) Utermöhl and Koppe. (*Achromatium*) *mobi e* Lauterborn, Verhandl. Naturhist.-Medizin. Vereins, Heidelberg, N. F., *13*, 1915, 413; *Microspira vacillans* Gicklhorn, Cent. f. Bakt., II Abt., *50*, 1920, 422; Utermöhl and Koppe, Verhandl. Intern. Ver. f. theoret. u. angew. Limnologie, 1923, 86 and Utermöhl and Koppe, Arch. f. Hydrobiol., Suppl. Bd. *5*, 1925, 234.)

Colorless sulfur bacteria, always occurring singly, slightly curved, elongated ellipsoids or cylinders with broad hemispherical ends. Length varies from 12 to 30 microns, width from 8 to 14 microns; most common size 20 by 9 microns. Multiplication by constriction in the middle.

Cells actively motile by means of a single polar flagellum, distinctly visible without special staining. It is 20 to 40 microns long, and, with respect to the direction of motion, always posteriorly placed. Rate of movement somewhat sluggish, about 800 microns per minute, probably on account of high specific gravity of cells.

Normally contain small sulfur droplets and, in addition, large, roughly spherical inclusions of calcium carbonate. Two to four such crystal masses almost fill a single cell. Under unfavorable conditions the calcium carbonate crystals may disappear before the sulfur globules.

Microaerophilic; apparently require hydrogen sulfide.

Habitat: Fresh water environment containing sulfide and calcium ions; in shallow basins and streams in the upper layers of the mud.

2. **Macromonas bipunctata** (Gicklhorn) Utermöhl and Koppe. (*Pseudomonas bipunctata* Gicklhorn, Cent. f. Bakt., II Abt., *50*, 1920, 425; Utermöhl and Koppe, Arch. f. Hydrobiol., Suppl. Bd. *5*, 1925, 235.)

Cells colorless, occurring singly, cylindrical with hemispherical ends; after cell division often temporarily pear-shaped. Length 8 to 12 microns, width 3 to 5 microns. Multiplication by constriction in the middle.

Actively motile by means of a single polar flagellum, about 10 to 15 microns long, and always posteriorly placed with respect to the direction of movement. Flagellum delicate, not visible without staining. Rate of movement sluggish, about 600 microns per minute. Probably this slow motion is on account of the high specific gravity of the cells.

Normally contain calcium carbonate crystals as inclusions. These are in the form of large spherules, one or two of which nearly fill the individual cells. Sulfur globules have not been demonstrated with certainty as yet.

Microaerophilic, but it is uncertain whether hydrogen sulfide is required.

Source: From stems, leaves, etc. of fresh water plants in ponds near Graz, Austria.

Habitat: Fresh water environments containing calcium ions; but it has been found in sulfide-containing as well as in sulfide-free water. In shallow basins and streams in upper layers of the mud.

Note: Another species in this genus is *Macromonas hyalina* (Gicklhorn) Utermöhl and Koppe. (*Pseudomonas hyalina* Gicklhorn, Cent. f. Bakt., II Abt., *50*, 1920, 426; Utermöhl and Koppe, Arch. f. Hydrobiol., Suppl., *5*, 1925, 235.) Similiar to *Macromonas bipunctata.*

APPENDIX TO ORDER CHLAMYDOBACTERIALES

A recently recognized order of filamentous bacteria includes organisms similar in many ways to those included in *Chlamydobacteriales*.

ORDER CARYOPHANALES PESHKOFF.*

(Jour. Gen. Biol., (Russian), *1*, 1940, 611, 616.)

Filamentous or bacillary bacteria of variable size characterized either by the presence of a central body or a ring-like nucleus which frequently takes the form of a disk. These bodies are clearly visible in the living cells. The nuclear elements give a clear-cut Feulgen reaction. The filaments may be enclosed in a sheath. Colorless. The individuals consist of cylindrical cells enclosed in a continuous sheath or they are tube-like coenocytic organisms containing varying numbers of ring or disk-like nuclei separated from each other by alternating protoplasmic segments. These may disintegrate into mononucleate coccoid cells. Gonidia sometimes formed. Found in water and in the intestines of arthropods and vertebrates.

FAMILY I. PONTOTHRICACEAE PESHKOFF.

Jour. Gen. Biol. (Russian), *1*, 1940, 611, 616.)

Long, unbranched filaments which consist of separate cells in a continuous sheath. Multiplication by cell division, homogonia and unicellular gonidia. Resemble the blue green algae but they are non-motile and photosynthetic pigments are lacking. Free living forms.

Genus I. **Pontothrix** *Nadson and Krassilnikow.*

(Comp. rend. Acad. Sci. de U.R.S.S., A, No. 1, 1932, 243–247.)

Characters as for the family.

The type species is *Pontothrix longissima* (Molish) Nadson and Krassilnikow.

1. **Pontothrix longissima** (Molish) Nadson and Krassilnikow. (*Chlamydothrix longissima* Molish, Cent. f. Bakt., II Abt., *33*, 1912, 60; Nadson and Krassilnikow, *loc. cit.*, 243.) Cells in the filaments, 1.5 to 2.0 by 1.0 to 5.0 microns. Filaments 0.5 cm in length. Cells show a central chromatin body. Found on *Zostera marina* in the Bay at Sebastopol on the Black Sea.

FAMILY II. ARTHROMITACEAE PESHKOFF.

(Jour. Gen. Biol. (Russian), *1*, 1940, 611, 616.)

Filaments probably divided into cells although septa (protoplasmic?) disappear during sporulation. Disk-like nuclei alternate with thin protoplasmic segments (septa). Spores form in the distal ends of filaments. Non-motile. The filaments are attached by a spherical body in groups to the intestinal wall of insects, crustaceans and tadpoles.

Genus I. **Arthromitus** *Leidy.*

(Proc. Acad. Nat. Sci., Philadelphia, *4*, 1849, 227.)

Characters as for the family. Although the description is worded somewhat differently, there does not seem to be any essential difference between this and the following genus.

The type species is *Arthromitus cristatus* Leidy.

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* Arranged by Prof. Michael A. Peshkoff, Institute of Cytology, Acad. of Sci., Moscow, U.S.S.R., April, 1947.

1. **Arthromitus cristatus** Leidy. (Proc. Acad. Nat. Sci., Phila., *4*, 1849, 227 and Jour. Acad. Nat. Sci. Phila., *8*, 1881, 443.) From the intestine of the milliped (*Julus marginatus*) and the termite (*Reticulitermes flavipes*). Filaments delicate, straight or inflected, growing in tufts usually of moderate density, from minute, attached, yellowish rounded or oval bodies. Articuli short, cylindric, uniform, length 2.75 microns, width 0.6 micron, no trace of interior structure. Length of filament 67 to 543 microns, breadth 0.6 micron.

2. **Arthromitus intestinalis** (Valentin) Peshhoff. (*Hygrocrocis intestinalis* Valentin, Report. f. Anat. u. Phys., *1*, 1836, 000; Peshhoff, Jour. Gen. Biol. (Russian), *1*, 1940, 597.) From the intestine of the cockroach (*Blatta orientalis*). Chatton and Perard (Compt. rend. Soc. Biol., Paris, *74*, 1913, 1160) conclude that this species and *Arthromitus cristatus* Leidy are of the same genus although they accept the name *Hygrococis* as having priority. However, the latter is invalid as a bacterial genus because it was given earlier as the name of a genus of algae. See Buchanan, General Systematic Bacteriology, 1925, 183.

3. **Arthromitus nitidus** Leidy. (Smithsonian Contributions to Knowledge, *5*, 1852, 35.) From the intestine of the milliped (*Julus marginatus*).

4. **Arthromitus batrachorum** Collin. (Arch. Zool. Expér. et Gén., *51*, 1913, 63.) From the alimentary tract of toad tadpoles (*Bufo calamita*).

Genus II. Coleomitus *Duboscq and Grassé.*

(*Coleonema* Duboscq and Grassé, Arch. Zool. Expér. et Gén., *68*, 1929, Notes et Revue, 14; not *Coleonema* Bartl. and Wendl., 1924, fam. *Rutaceae*; Duboscq and Grassé, Arch. Zool. Expér. et Gén., *70*, 1930, N. et R., 28.)

Long filaments, divided by partitions. Bacillary elements in basal region. Ovoid or ellipsoidal spores in other parts of filament originating by transformation from these bacillary elements through sporoblasts.

The type species is *Coleomitus pruvoti* Duboscq and Grassé.

1. **Coleomitus pruvoti** (Duboscq and Grassé) Duboscq and Grassé. (*Coleonema pruvoti* Duboscq and Grassé, Arch. Zool. Expér. et Gén., *68*, 1929, Notes et Revue, 14; Arch. Zool. Expér. et Gén., *70*, 1930, N. et R., 28.) In the intestine of a termite (*Kalotermes sp.*) from the Loyalty Islands.

Filaments with hyaline sheath, length variable up to 320 microns, breadth 1.3 microns. Bacillary elements 3 to 4 microns long, also elements up to 6 microns with a chromatic granule or disc in the middle of the body. Spores ellipsoidal 0.8 to 0.9 by 1.7 to 2.0 microns, all containing an excentrically placed granule of volutin.

FAMILY III. OSCILLOSPIRACEAE PESHKOFF.

(Jour. Gen. Biol. (Russian), *1*, 1940, 611, 616.)

Bacillary and filamentous forms. Filaments are most probably partitioned to form narrow cells each containing a central chromatin body (disk-like nucleus). These give a clear Feulgen reaction, and are embedded in hyaline protoplasm. Spores are formed by a fusion of 2–3 protoplasts of neighboring cells. Actively motile. The character of the motion suggests the presence of peritrichous flagella. Parasitic in the intestinal tract of vertebrates.

Genus I. **Oscillospira** *Chatton and Perard.*

(Comp. rend. Soc. Biol., Paris, *65*, 1913, 1159.)

Characters as for the family.

The type species is *Oscillospira guilliermondii* Chatton and Perard.

1. **Oscillospira guilliermondii** Chatton and Perard. (Chatton and Perard, *idem.*) From the intestine of a guinea pig. Spores 2.0 by 4.0 to 5.0 microns (Krassilnikow, Microbiol. Jour. (Russian), *6*, 1928, 249).

FAMILY IV. CARYOPHANACEAE PESHKOFF.

(Jour. Gen. Biol. (Russian), *1*, 1940, 611, 616.)

Large filamentous and bacillary forms. Individuals not divided into cells; they are virtually coenocytic tubular organisms containing alternating ring, horseshoe or disk-like nuclei and protoplasmic segments. Such nuclei are most comparable with single chromosomes reproducing themselves by means of a true endomitosis (Peshkoff, Nature, *154*, 1946, 137). No spores formed. When motile, possess peritrichous flagella. They are found on the mucous membranes of the mouth cavities of man and various animals, and in the alimentary tracts of ruminants.

Genus I. **Caryophanon** *Peshkoff.*
(*Loc. cit.*)

Characters as for the family.

The type species is *Caryophanon latum* Peshkoff.

1. **Caryophanon latum** Peshkoff. (Compt. rend (Doklady) Acad. Sci., U.R.S.S. Nouvelle série, *25*, 1939, 244; Jour. Gen. Biol. (Russian), *1*, 1940, 527; Microbiology (Russian), *15*, 1946, 189.)

Slightly curved rods 3.1 by 15 to 20 microns. Grow on cow manure-extract agar pH 7.8 to 8.0. Also grow on yeast-extract agar at same pH. Aerobic. Isolated from 20 to 30 per cent of samples of fresh cow manure. Non-pathogenic. Isolated at least 20 times in Moscow (U.S.S.R.) and its vicinity by Peshkoff. In 1945 isolated and successfully cultivated in England by Robinow and Pringsheim. Apparently ubiquitous, connected with ruminants. Colonies round, 1 to 2 mm in diameter with slightly undulate margins. Subject to distinct S-R variation. R forms tend to grow in long motile filaments and are much thinner than the plump S individuals. May occur in the form of mononucleate coccoids (especially on yeast-extract agar) and polynucleate bacilli. When grown from old cultures may develop irregular giant forms.

2. **Caryophanon tenue** Peshkoff. (Comp. Rend. (Doklady) Acad. Sci. U. R. S. S., Nouvelle Sér., *25*, 1939, 244; Jour. Gen. Biol. (Russian), *1*, 1940, 597.)

Similar to the above species, but more slender. Diameter 1.5 microns. Grows on cow manure extract agar and yeast-extract agar at pH 7.8 to 8.0. From fresh cow manure.

3. **Caryophanon muelleri** *comb. nov.* (*Simonsiella muelleri* Simons, Cent. f. Bakt., I Abt., Orig., *88*, 1922, 50.) Non-motile. Found on mucous membrane of oral cavity of healthy humans, 3.0 to 4.5 by 10.0 microns.

4. **Caryophanon crasse** *comb. nov.* (*Simonsiella crassa* Simons, *loc. cit.*, 509.) Non-motile. Found on mucous membrane of domestic animals.

5. **Caryophanon filiformis** *comb. nov.* (*Simonsiella filiformis* Simons, *loc. cit.*, 509.) Long filaments from mucous membrane of oral cavity of domestic animals.

ORDER IV. MYXOBACTERIALES JAHN.*

(Kryptogamenflora der Mark Brandenburg, V, Pilze 1, Lief. 2, 1911, 201.)

Synonymy: *Myxobacteriaeae* Thaxter, Bot. Gaz., *17*, 1892, 389; *Myxobactrales* Clements, The genera of fungi. Minneapolis, 1909, 8; *Synbacteriés* Pinoy, Compt. rend. Acad. Sci., Paris, *157*, 1913, 77; *Myxobactericae* Heller, Jour. Bact., *6*, 1921, 521; *Polyangidae* Jahn, Beiträge zur botanischen Protistologie, I, Die Polyangiden, Geb. Borntraeger, Leipzig, 1924; *Myxobacteriae* Stanier and van Niel, Jour. Bact., *42*, 1941, 437.

The name *Myxobacteriaceae*, although having the form of a family designation, was proposed by Thaxter (*loc. cit.*) in an article bearing the title "On the *Myxobacteriaceae*, a new order of *Schizomycetes*." Apparently the first ordinal name was that given by Clements (*loc. cit.*), but does not follow the spelling fixed by the precedent of Thaxter. The revised spelling was given by Jahn as *Myxobacteriales*. Pinoy (*loc. cit.*) suggested *Synbacteriés*. The name *Myxobacterieae* was proposed by Heller (*loc. cit.*) as a class designation, *Bacteria* being regarded as the designation of a phylum. *Polyangidae* is likewise a class designation, Jahn (1924, *loc. cit.*) concluding this group should be coordinate in rank with the *Schizomycetes*. Buchanan (Jour. Bact., *3*, 1918, 541) proposed the name *Myxobacteriales*, not knowing of the previous use of the term. He has therefore at times been incorrectly designated as the author of the name.

It may be argued that a more appropriate ordinal designation might be *Polyangiales*, inasmuch as the generic name *Myxobacter* proposed by Thaxter was soon found to be a synonym of *Polyangium* Link. However, there would seem to be justification of the retention of a name based upon an "ancient generic name" in Rule 21 of the Brussels Code.

The group is herein regarded as an order, though Jahn, and Stanier and van Niel agree in regarding it as a class.

Common or trivial names. The slime bacteria, myxobacteria or polyangids.

Brief characterization of the order. The relatively long, slender, flexible, non-flagellate vegetative cells produce a thin, spreading colony (pseudoplasmodium, swarm). The cells are often arranged in groups of 2 or 3 to a dozen or more, their long axes parallel. The group moves as a unit, by means of a crawling or creeping motion, away from the center of the colony. The moving cells pave the substrate with a thin layer of slime on which they rest.

During sporulation (which occurs in all forms except members of the genus *Cytophaga*) the cells are much shortened, in some cases becoming spherical or coccoid, thick-walled and highly refractile. Fruiting bodies are formed by the species of all families except the *Cytophagaceae* and the genus *Sporocytophaga* of the family *Myxococcaceae*. The fruiting bodies may consist of aggregations of cysts in which the spores (resting cells) are inclosed, or of masses of mucilaginous slime surrounding large numbers of shortened, rod-shaped, or coccoid spores. Fruiting bodies may be sessile or stalked. They are usually pigmented a bright shade of orange, yellow, red or brown, though colorless fruiting bodies, as well as black, have been described.

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* The section covering the order *Myxobacteriales* was first developed in its present form by Professor R. E. Buchanan, Iowa State College, Ames, Iowa, for the fourth edition of the Manual issued in 1934. It was revised by Professor Buchanan for the fifth edition in 1939. The present review has been carried out by Dr. J. M. Beebe and Professor R. E. Buchanan who had had material assistance from Dr. R. Y. Stanier, April, 1943.

Members of the genus *Sporocytophaga* are not known to produce fruiting bodies as such, but often dense agglomerations of shortened rods or cocci have been noted; these may be interpreted as primitive forms of fruiting bodies.

Physiologically most species show great similarity, preferring substrates rich in cellulosic or other complex carbohydrate materials.

Most of the known species are saprophytic or coprophilic and may be found on dung, in soil, on rotten wood, straw, leaves, etc. They frequently appear to live in close association with various true bacteria and are probably parasitic on them. Many have been cultivated on dung. One species is aquatic and parasitic on an alga, *Cladophora sp.* (Geitler, Arch. f. Prostistenol., *50*, 1924, 67). One is parasitic (?) on lichens and some are halophilic marine forms (Stanier, Jour. Bact., *40*, 1940, 623). Another species is reported as pathogenic for fish (Ordal and Rucker, Proc. Exper. Biol. and Med., *56*, 1944, 15).

Culture media. The myxobacteria are frequently cultured by transferring to dung. For certain species sterilized dung has been reported as less favorable than the unsterilized. Dung decoction agar has often been employed. Among the early investigators, Quehl (Cent. f. Bakt., II, Abt., *16*, 1906, 9) secured slow growth of some species on malt extract-gelatin at 18° to 20°C with digestion of the gelatin. Potato-nutrient agar was reported better than dung agar, while no growth occurred on sterilized potato alone. Peptone was considered necessary; glucose had little effect. Pinoy (Comp. rend. Acad. Sci., Paris, *157*, 1913, 77) claimed that satisfactory development of *Chondromyces crocatus* depended upon the presence of a species of *Micrococcus* in the medium. Kofler (Sitzber. d. k. Akad. Wiss., Wien, Math. Nat. Klasse, 122 Abt., 1913, 845) successfully used a sucrose-peptone agar to which was added potassium and magnesium salts.

Recent evidence indicates that the carbon requirements of these organisms are met satisfactorily by the more complex carbohydrates, and frequently by their products of hydrolysis. Mishustin (Microbiology, Moscow, 7, 1938, 427), Imšenecki and Solntzeva (Microbiology, Moscow, *6*, 1937, 3), Krzemieniewski and Krzemieniewska (Acta Soc. Bot. Pol., *5*, 1927, 102) and others have reported good growth of several species of myxobacteria on cellulose.

Beebe (Jour. Bact., *40*, 1940, 155) claimed several species to be facultative parasites on various true bacteria. Good growth was obtained on suspensions of killed bacterial cells in 1.5 per cent agar. Sniesko, Hitchner and McAllister (Jour. Bact., *41*, 1941, 26) showed the destruction of living bacterial colonies by colonies of myxobacteria.

Temperature range. Most species cultivated in the laboratory show a minimum between 17° and 20°C though some species grow at 10°C. Maximum growth usually occurs at about 35°C and the maximum growth temperature is about 40°C. More normal fruiting bodies are produced at lower temperatures.

The Krzemieniewskis (Acta Soc. Bot. Pol., *5*, 1927, 102) report that the fruiting bodies of *Melittangium boletus*, *Myxococcus virescens*, *Chondrococcus coralloides*, *Archangium gephyra* and *Archangium primigenium* var. *assurgens* first develop, followed by *Polyangium fuscum* and *P. fuscum* var. *velatum*. At 30°C they appear in about 5 to 7 days, at 17° to 20°C in 8 to 12 days, and at 11° to 14°C in 24 to 30 days. Each 10°C rise in temperature approximately halves the time. Other species are slower in developing.

The vegetative rods. The vegetative cells are long, flexuous rods, often 30 times as long as broad. Thaxter noted rods up to 15 microns in length though these appear abnormally long. In general the cells are cylindrical, more rarely tapered or pointed at the ends. Jahn (1924, *loc. cit.*) described spindle-shaped cells. Thaxter (Bot. Gaz., *37*, 1904, 405) believed that a highly elastic wall was present; other authors have

failed to prove it by plasmolytic agents. Jahn states that tinctorial and chemical methods failed to definitely show the presence of a membrane, but that the elasticity of the cells show this clearly. The cells are flexible, not rigid as are ordinary bacteria. Beebe (Jour. Bact., *41*, 1941, 214) reported the presence of a cell membrane in *Myxococcus xanthus*, often made visible with proper staining procedures. The cells frequently show one or more refractive granules. Thaxter also noted nucleus-like granules in the spores of *Myxococcus*, while Bauer (Arch. f. Protistenk., *5*, 1905, 92) reported that during germination of the spores of *Myxococcus* a refractile granule is found at each end of the cell. Badian (Acta Soc. Bot. Pol., *7*, 1930, 55) stated that the cell of *Myxococcus virescens* lacks a true nucleus, but that there is present a basophilic structure probably nuclear in nature. It is dumb-bell-shaped and divides longitudinally in mitosis. In spore formation an autogamy occurs followed by what appears to be a reduction division. All chromatin material was Gram-negative except during reduction; it may be stained by hematoxylin. Beebe noted a condensed mass of nuclear material in the vegetative cells of *Myxococcus xanthus* that divided by constriction prior to each cell fission. Nuclear division is considered to be non-random amitosis. Cell division is by means of constriction at a point near the center and is always complete. The nucleus is stained by gentian violet and by iron-hematoxylin and gives a faintly positive Feulgen reaction. What appears to be an autogamous fusion of chromosomes takes place during sporulation, followed by a nuclear division during germination of the spores. The spores germinate by a process analagous to budding. Vahle (Cent. f. Bakt., II Abt., *25*, 1909, 178) found fat globules and occasional small volutin granules in 3 to 4 day old cultures. Glycogen was not found.

In masses the vegetative rods may be somewhat reddish in color. Thaxter suggested the possibility that the color might be bacteriopurpurin. Treated with concentrated sulfuric acid the pigment gives a blue reaction, hence Jahn (1924, *loc. cit.*) concludes it to be carotin.

Motility of the cells. Baur (*loc. cit.*) states that cells have a power of forward movement at a rate of about 10 microns per minute. No flagella are present. The cells do not "swim." They may bend and are unlike most true bacteria in this respect, though Dobell (Quart. Jour. of Microscop. Science, *56*, 1911, 395 and Arch. f. Protistenkunde, *26*, 1912, 117) describes such flexibility for the giant bacteria (see *Bacillus flexilis*). This is characteristic also of *Beggiatoa*, *Oscillatoria* and *Spirochaeta*.

The cells *en masse* move in a "front," advancing and leaving behind a slime. The cells in general tend to lie on rather than in the slime. The exact mechanism of motion has proved puzzling. Jahn believes the motion to be related to that of forms like *Oscillatoria*, and to be due to excretion of slime from the cell, probably an asymmetrical excretion which pushes the cell along.

The colony. This has been variously termed a swarm, pseudoplasmodium, plasmodium and reproductive communalism. It bears a faintly superficial resemblance to the plasmodium of certain of the slime molds (*Myxomycetes*) but differs in that the true plasmodium is composed of the fused bodies of large numbers of amoeboid cells. The myxobacterial colony is an aggregation of individual rod-shaped, bacterial cells that are not amoeboid. The slime produced by the cells is not protoplasmic, and the colony is not motile but increases in size as the cells move away from the center. Larger numbers of cells are to be found at the margins than on the central portions of the colony; in consequence, fruiting bodies tend to be found in concentric rings on the colony. The cells lie on the surface of the slime which they secrete, not in it.

Thaxter proposed the term "pseudoplasmodium" as a satisfactory descriptive name for the vegetative colony, while Jahn preferred the use of "swarm stage." Inasmuch as the term "colony" in relation to bacterial growth implies large numbers of vegetative cells developing as a unit without regard for size, shape or structure, it is equally suitable. Stanier (Bact. Rev., *6*, 1942, 183) speaks of the condition as "reproductive communalism."

Pigmentation of the fruiting bodies is commonly employed in the differentiation of species. Species that produce colorless cysts and some with black pigment have been reported; in general the fruiting bodies are brightly colored in shades of yellow, red, orange or brown. The color seems to originate in the slime or cyst walls rather than in the encysted cells; its nature is not well understood. The Krzemieniewskis (Bull. Acad. Polon. Sci. Lettres, Classe Sci. Math. Nat., Sér. B, Sci. Nat., I, 1937, 11) noted that the orange-red fruiting bodies of *Sorangium compositum* became gray-brown in strong alkali; the pigment was highly soluble in acetic acid and alcohol and easily soluble in ether and chloroform. It was insoluble in benzol, carbon di-sulfide and petroleum ether. They suggested that it was a carotin derivative rather than true carotin.

Beebe (1941, *loc. cit.*) found that the pigments of *Polyangium fuscum*, *Podangium erectum*, *Myxococcus virescens*, *Chondrococcus blasticus* and *Myxococcus xanthus* gave typical carotin reactions in concentrated sulfuric acid, but were insoluble in chloroform, ether, acetone and methyl and ethyl alcohol. An atypical carotin reaction resulted with hydrochloric and nitric acids. He concluded the pigments to be related to the carotins.

The fruiting bodies. After growth as a vegetative colony the pseudoplasmodium usually forms fruiting bodies which may in the different species be of many shapes and sizes. Differentiation of species, genera and families is based almost entirely upon the character of fruiting body developed. In some cases a stalk is produced, in some not.

In some forms the stalk is delicate and white, consisting of little-changed slime, in other cases it may be stiff and colored. The rods evidently are carried up by the slime which they secrete. In some forms the stalk is simple and short, in others relatively long and branched.

The rods ordinarily associate in more or less definite clumps to form cysts. These cysts may be sessile or stalked. Usually the rods shorten and thicken materially before the cyst ripens. In some forms they shorten so much as to become short ovoid or cylindrical, functioning as spores. They are not endospores such as are found in the genus *Bacillus*.

The cysts may or may not possess a definite membrane produced from slime. Usually the cysts are bright colored, frequently red, orange or yellow. The spores within the cysts when dried retain their vitality for considerable periods of time. Jahn records germination of *Polyangium fuscum* after 5¾ years, of *Myxococcus fulvus* after 8 years.

Methods of isolation. One technic of isolation used by the Krzemieniewskis (1927, *loc. cit.*) was to sieve the fresh soil, place it on blotting paper in petri dishes, and add sterilized rabbit dung. The soil was saturated with water to 70 to 100 per cent, and the plates incubated at 26° to 30°C. After 5 to 10 days fruiting bodies began to appear on the dung. Numerous species were isolated by this method.

Mishustin (*loc. cit.*) employed silica gel plates on the surface of which sterilized filter paper had been placed. Small lumps of soil were placed on the filter paper and the plates incubated for several days at various temperatures. Vegetative myxo-

bacterial colonies developed around the inocula and were purified by transfer to fresh cellulose plates.

Beebe reported a modified Krzemieniewski technic to be satisfactory. Fruiting bodies that had developed on sterilized rabbit dung were transferred to bacterial suspension agar plates. Associated bacteria failed to grow well, but myxobacteria developed rapidly.

The species of the genera *Cytophaga* and *Sporocytophaga* require special technics (Stanier, Bact. Rev., *6*, 1942, 143). The soil forms which decompose cellulose may be enriched with a medium consisting of cellulose (usually in the form of filter paper) and a neutral or slightly alkaline mineral base containing either ammonium or nitrate salts as nitrogen source. For certain species chitin may be substituted for cellulose. Pure cultures may be secured by use of soft agar (1 per cent or less) with finely divided cellulose or with cellulose dextrins (Fuller and Norman, Jour. Bact., *46*, 1943, 281).

Cultivation of organisms. Pure cultures of many species have been grown upon various media and substrates. Sterilized dung, dung decoction agar, nutrient agar, potato and potato agar, sterilized lichens, etc. have all been used. Little study has been made of the food requirements. Recent evidence indicates the utilization of some of the more complex carbohydrates. Imšenecki and Solntzeva (Microbiology, Moscow, *6*, 1937, 3) reported the growth of certain species on cellulose with partial decomposition of that compound. Mishustin (Microbiology, Moscow, *7*, 1938, 427) isolated five species of cellulose-decomposing myxobacteria, cultivating them on a mineral salt-silica gel medium to which filter paper had been added as a source of carbon. Krzemieniewska (Acta. Soc. Bot. Polon., *7*, 1930, 507) grew species of the *Cytophagaceae* on cellophane, while Stapp and Bortels (Cent. f. Bakt., II Abt., *90*, 1934, 28) record the growth of other members of the same family on media containing such carbon sources as mannitol, glucose, sucrose, dextrin, cellotriose and cellobiose. Inorganic nitrogen sources compared favorably with organic, in some cases appearing to be preferable. Stanier (Jour. Bact., *40*, 1940, 623) observed peptone and yeast extract to be the only suitable nitrogen sources for the *Cytophagaceae*, inorganic salts and amino acids failing in this respect. Agar and cellulose were decomposed, while chitin and starch were not utilized. Johnson (Jour. Bact., *24*, 1932, 335) and Benton (Jour. Bact., *29*, 1935, 449) both reported chitinovorous myxobacteria. Beebe (Iowa State Coll. Jour. Sci., *15*, 1941, 319 and *17*, 1943, 227) claimed growth of species of *Polyangium*, *Podangium*, *Chondrococcus* and *Myxococcus* on 1.5 per cent agar with no other nutrients added. Peptone appeared to aid development, while the addition of beef extract had no favorable effect. Moderate growth occurred on a mineral salt-agar medium without the addition of carbon or nitrogen sources. Growth was stimulated by the addition of various complex carbohydrates including cellulose and starch, the latter being hydrolyzed; complete inhibition resulted with pentoses and hexoses. Best growth was reported on a medium composed of dried bacterial cells suspended in 1.5 per cent agar. The suspended cells were lysed by the myxobacteria.

The Krzemieniewskis (Acta Soc. Bot. Pol., *5*, 1927, 102) showed that the optimum hydrogen ion concentrations for growth of different species were found between pH 3.6 and 8.0. Beebe (1941, *loc. cit.*) reported no growth of any species below pH 6.0, while moderate development was noted up to pH 9.0.

Habitat and distribution. Many species have been described from dung. The work of the Krzemieniewskis (Acta Soc. Bot. Pol., *5*, 1927, 102), Mishustin (Microbiology, Moscow, *7*, 1938, 427), Imšenecki and Solntzeva (*loc. cit.*) and others seems to indicate that they occur commonly in soils, particularly soils under cultivation or high in organic materials. Different species appear to be characteristic of various

types of soils. *Polyangium cellulosum* var. *ferrugineum* Mishustin and *Polyangium cellulosum* var. *fuscum* Mishustin (*loc. cit.*) were observed to be common in the black soils of Eastern European Russia, while a similar variety of the same species was reported only from podzol soils. Species of the families *Polyangiaceae*, *Sorangiaceae* and to a lesser degree *Archangiaceae* appear to predominate in Russian and European soils, while the soils of Central and Western United States seem to be more suitable for the growth of the *Myxococcaceae*. Soils of mountainous regions are said to contain fewer numbers of myxobacteria than those of lowland areas.

The distribution of myxobacteria in the soil seems to show a relationship to the hydrogen ion concentration. Some species are found only in neutral or alkaline soils (pH 7.0 to 8.0), others only in acid soils (pH 3.6 to 6.4). Some species show a wide tolerance (pH 3.6 to 8.0).

Relationships of the Myxobacteria. The resemblance of the pseudoplasmodium of the myxobacteria to the plasmodium of the slime molds is as noted above probably to be regarded as without significance, as is also the superficial resemblances of the fruiting bodies of the two groups. Jahn (1924, *loc. cit.*) dismisses the relationship to the *Thiobacteriales* suggested by Thaxter as improbable. Thaxter believed the possession of the red color might show presence of bacteriopurpurin; but Jahn found a carotin reaction which argues against this idea. Jahn insists upon a close relationship to the blue-green algae, particularly because of the mobility of the cells and the creeping motion. He does not believe all *Schizophytae* that do not belong to the *Cyanophyceae* (blue-green algae) should be grouped as bacteria. He believes the myxobacteria to be more closely related to the blue-green algae than to the true bacteria, and creates the class *Polyangidae* to be coordinate with the class *Schizomycetes*. In this he ignores the equal evidence of close relationship of the sulfur bacteria to the *Cyanophyceae*. His argument would lead to the recognition of all the orders of bacteria recognized in this MANUAL as classes. The wisdom of this is not apparent. The *Myxobacteriales* may be regarded as a well-differentiated order of the *Schizomycetes* showing some resemblance to the true bacteria on the one hand and the *Myxophyceae* (*Cyanophyceae*) and *Thiobacteriales* on the other.

Families of the Myxobacteriales. The division of the order *Myxobacteriales* into families has been based, in all classifications proposed, upon morphology. The final demonstration by Stanier (Jour. Bact., *40*, 1940, 636) of the close relationship between species of the genus *Cytophaga* and the myxobacteria led him to propose the recognition of a new family, *Cytophagaceae*.

The principal character differentiating this family from the four previously recognized is the absence of differentiated fruiting bodies. The resting cells are rod-shaped in the genus (*Cytophaga*). In another genus recognized by Stanier (*Sporocytophaga*) the resting cells are spherical. This brings the taxonomist face to face with the problem of deciding whether the presence of fruiting bodies or the spherical shape of the spores should be the primary basis of differentiation. The formation of spherical spores is believed to be of sufficient significance to require the inclusion of all organisms producing such in the family *Myxococcaceae*. *Sporocytophaga*, although it produces no fruiting body, is therefore placed in this family, while those forms which produce neither spherical spores nor fruiting bodies (genus *Cytophaga*) are placed in the new family *Cytophagaceae*.

Krzemieniewska's (Acta Soc. Bot. Pol., 7, 1930, 507 and Arch. Microbiol., 4, 1933, 394) conclusion that two distinct cell shapes appear in the myxobacteria (short, thick rods with ends almost truncate, and long, slender rods almost spindle-shaped in some cases with pointed tips) is supported by Stanier (Bact. Rev., *6*, 1942, 143) as also the

conclusion that the family *Archangiaceae* should be abandoned (Krzemieniewski and Krzemieniewska, Bull. Acad. Pol. Sci. Lettres, Classe Sci. Math. Nat., Sér. B., Sci. Nat., I, 1937, 11–31) and the genera and species redistributed. The validity of the argument is accepted, but the family is retained until a satisfactory revision can be effected. This should be based on a careful comparative study of the species.

Key to the Families of Order **Myxobacteriales.**

I. Neither definite fruiting bodies (cysts) nor spores (microcysts) produced.
Family I. *Cytophagaceae*, p. 1012.

II. Spores (resting cells, microcysts) produced.
- A. Resting cells (spores, microcysts) elongate, not spherical or ellipsoidal. Fruiting bodies (cysts) produced.
  - 1. Fruiting bodies (cysts) not of definite shape; cells heap up to produce mesenteric masses or finger-like (columnar) bodies.
Family II. *Archangiaceae*, p. 1017.
  - 2. Fruiting bodies (cysts) of definite shape.
    - a. Cysts usually angular. Vegetative cells usually thick and short, with blunt, rounded ends.
Family III. *Sorangiaceae*, p. 1021.
    - aa. Cysts usually rounded. Vegetative cells long and thin, sometimes spindle-shaped with pointed ends.
Family IV. *Polyangiaceae*, p. 1025.
- B. Resting cells (spores, microcysts) spherical or ellipsoidal. Fruiting bodies produced except in genus *Sporocytophaga*.
Family V. *Myxococcaceae*, p. 1040.

FAMILY I. CYTOPHAGACEAE STANIER.

(Jour. Bact., *40*, 1940, 630.)

Flexible, sometimes pointed rods, showing creeping motility. No fruiting bodies or spores (microcysts) formed. There is a single genus *Cytophaga*.

Genus I. **Cytophaga** *Winogradsky.*

(Ann. Inst. Pasteur, *43*, 1929, 578.)

Diagnosis: As for family. From Greek *kytos*, hollow place or cell; and *phagein*, to eat, devour.

The type species is *Cytophaga hutchinsonii* Winogradsky.

Key to the species of genus **Cytophaga.**

I. From soil.
  A. Do not utilize starch.
    1. Produce yellow pigment on cellulose.
      1. *Cytophaga hutchinsonii.*
      2. *Cytophaga lutea.*
    2. Produces orange pigment on cellulose.
      3. *Cytophaga aurantiaca.*
    3. Produces pink pigment on cellulose.
      4. *Cytophaga rubra.*
    4. Produces olive-green pigment on cellulose.
      5. *Cytophaga tenuissima.*
  B. Utilize starch.
    1. Produces yellow to orange pigment on starch.
      6. *Cytophaga deprimata.*
    2. Produces cream to pale yellow pigment on starch.
      7. *Cytophaga albogilva.*

II. From sea water.
  A. Dark pigment on cellulose.
      8. *Cytophaga krzemieniewskae.*
  B. No pigment on cellulose.
      9. *Cytophaga diffluens.*
  C. Liquefies agar.
      10. *Cytophaga sensitiva.*

1. **Cytophaga hutchinsonii** Winogradsky. (Winogradsky, Ann. Inst. Pasteur, *43*, 1929, 578; *Cytophaga* strain 8, Jensen, Proc. Linn. Soc. N. S. Wales, *65*, 1940, 547; not *Cytophaga hutchinsoni* Imšenecki and Solntzeva, Bull. Acad. Sci. U.S.S.R., Ser. Biol., No. 6, 1936, 1129.)

Etymology: Named for H. B. Hutchinson.

Rods: Highly flexible, occurring singly, 0.3 to 0.4 microns wide at the center and tapering to both ends. Length 3.0 to 6.0 microns, according to Krzemieniewska (Arch. Mikrobiol., *4*, 1933, 396); 1.8 to 4.0 microns, according to Jensen (*loc. cit.*). May be straight, bent, U-shaped or S-shaped. Stain poorly with ordinary aniline dyes. With Giemsa's or Winogradsky's stain young cells are colored uniformly except for the tips, which remain almost colorless; in older cells there is a concentration of chromatin material at the center. Old cultures show large coccoid cells which are not readily seen. Gram-negative.

Growth on cellulose, cellobiose, cellulose dextrins and glucose. On mineral salts-silica gel plates covered with filter paper, bright yellow glistening mucilaginous patches are produced after a few days. The filter paper in these regions is gradually completely dissolved and the patches become translucent.

Ammonia, nitrate, asparagin, aspartic acid and peptone can serve as sources of nitrogen, according to Jensen (*loc. cit.*).

Strictly aerobic.

Optimum temperature 28° to 30°C.

Source: Isolated from soil.

Habitat: Soil. Decomposes plant residues.

2. **Cytophaga lutea** Winogradsky. (Ann. Inst. Pasteur, *43*, 1939, 599.)

Etymology: Latin *luteus*, yellow.

Dimensions of the cells approximately those of *Cytophaga aurantiaca* (see below) but rather larger and thinner and without marked central swelling. Gram-negative.

Produces a brilliant yellow pigment similar to that of *Cytophaga hutchinsonii*.

This species differs only in size from *Cytophaga hutchinsoni*, and is probably a variety of it.

Source: Isolated from soil.

Habitat: Soil. Decomposes plant residues.

3. **Cytophaga aurantiaca** Winogradsky. (Ann. Inst. Pasteur, *43*, 1929, 597; probably *Mycococcus cytophagus* Bokor, Arch. Microbiol., *1*, 1930, 34.)

Etymology: Modern Latin *aurantiacus*, orange-colored.

Cells 1.0 micron wide at the center by 6 to 8 microns long. Except for size, very similar to those of *Cytophaga hutchinsonii*. Gram-negative.

Produces orange mucilaginous patches on filter paper-silica gel plates. Fibrolysis is very rapid and intense.

Source: Isolated from soil.

Habitat: Soil. Decomposes plant residues.

4. **Cytophaga rubra** Winogradsky. (Ann. Inst. Pasteur, *43*, 1929, 598.)

Etymology: Latin *ruber*, red.

Pointed rods, straight or sometimes slightly bent, occasionally hooked at one end. Length approximately 3 microns. Gram-negative.

Produces diffuse, rapidly-spreading, pink to brick-red patches on filter paper-silica gel plates. Fibrolysis is much slower and less extensive than that caused by *Cytophaga hutchinsonii*.

Source: Isolated from soil.

Habitat: Soil. Decomposes plant residues.

5. **Cytophaga tenuissima** Winogradsky. (Ann. Inst. Pasteur, *43*, 1929, 599; incorrectly spelled *Cytophaga ternissima* in Bergey et al., Manual, 4th ed., 1934, 559.)

Etymology: Latin *tenuissimus*, most tenuous, very slender.

Dimensions of cells not given, but described as being extremely slender. Gram-negative.

Produces mucilaginous, greenish to olive patches on filter paper-silica gel plates.

Source: Isolated from soil.

Habitat: Soil. Decomposes plant residues.

6. **Cytophaga deprimata** Fuller and Norman. (Jour. Bact., *45*, 1943, 566.)

Etymology: Latin *deprimo*, to depress or sink down.

Rods: Long and flexuous with pointed ends, 0.3 to 0.5 by 5.5 to 10 microns, arranged singly. Creeping motility on solid surfaces. Gram-negative.

Growth on starch agar is at first smoky to faint yellow becoming bright yellow later. Colonies are irregular and concave in elevation. The edge spreads indistinguishably into the surrounding medium and shallow depressions develop around the colony. Small colonies give the plate a characteristic pitted appearance.

Growth on cellulose dextrin agar is

milky white. Colonies are depressed in medium.

Gelatin is liquefied in 4 days.

Glucose, lactose, maltose, sucrose, pectin, starch, cellulose dextrin and hemicellulose are utilized. Very scant growth on cellulose may be found on first isolation.

Yeast extract, ammonium nitrate and peptone are suitable nitrogen sources.

Indole not formed.

Nitrites not produced from nitrates.

No visible change in litmus milk.

Highly aerobic.

Optimum temperature 25° to 30°C.

Source: Isolated from soil.

Habitat: Soil. Decomposes organic matter.

7. **Cytophaga albogilva** Fuller and Norman. (Jour. Bact., *45*, 1943, 566.)

Etymology: Latin *albus*, white, and *gilvus*, pale yellow.

Long flexuous rods with pointed ends, 0.3 to 0.5 by 4.5 to 7.5 microns, arranged singly. Creeping motility on solid surfaces. Gram-negative.

Growth on starch agar is cream to pale yellow. Colonies are small, concave, and irregulary round. Edge is entire and irregular.

Growth on cellulose dextrin agar is restricted. Colonies are pin-point, milky white in color, round and concave.

Gelatin is liquefied in 7 days.

Glucose, galactose, lactose, maltose, sucrose, gum arabic, pectin, starch, cellulose dextrin and hemicellulose are utilized. Very scant growth on cellulose may be found on first isolation.

Ammonia, nitrate and peptone are suitable nitrogen sources.

Indole not formed.

Nitrites not produced from nitrates.

No visible change in litmus milk.

Highly aerobic.

Optimum temperature 22° to 30°C.

Source: Isolated from soil.

Habitat: Soil. Decomposes organic matter.

8. **Cytophaga krzemieniewskae** Stanier. (Incorrectly spelled *Cytophaga krzemieniewskii* in Stanier, Jour. Bact., *40*, 1940, 623; Jour. Bact., *42*, 1941, 532.)

Etymology: Named for H. Krzemieniewska.

Long, flexible rods, usually of even width with blunt ends, occasionally somewhat pointed and spindle-shaped, 0.5 to 1.5 by 5 to 20 microns. Star-shaped aggregates occur in liquid media. Creeping motility on solid surfaces, non-motile in liquids.

Growth on a sea water-peptone agar plate begins as a smooth, thin, pale pink, rapidly spreading swarm. After a few days, the older portions of the swarm assume a warty appearance due to the accumulation of cells in drop-like masses, resembling immature fruiting bodies but always containing normal vegetative cells. A diffusible brown to black pigment which masks the pink color of the swarm is produced after about a week. Agar is rapidly decomposed, and ultimately liquefaction becomes almost complete.

Sea water-gelatin stab: Liquefaction.

Growth in liquid media is turbid and silky with a pink sediment; the medium turns dark brown or black after 1 or 2 weeks.

Xylose, glucose, galactose, lactose, maltose, cellobiose, cellulose, alginic acid, agar and starch are utilized, but not arabinose, sucrose and chitin.

Yeast extract and peptone are the only suitable nitrogen sources known.

Weakly catalase positive.

Indole not formed.

Nitrites produced from nitrates.

Hydrogen sulfide not produced.

Salt concentration range: 1.5 to 5.0 per cent.

Strictly aerobic.

Optimum temperature 22° to 25°C.

Source: Isolated from sea water.

Habitat: Sea water. Probably on decaying marine vegetation.

9. **Cytophaga diffluens** Stanier. (Jour. Bact., *40*, 1940, 623; Jour. Bact., *42*, 1941, 546.)

Etymology: Latin *diffluens*, spreading, flowing away.

Pointed, sometimes spindle-shaped, flexible rods, 0.5 to 1.5 by 4 to 10 microns. In old cultures involution forms consisting of long, twisted, thin threads are found. Star-shaped aggregates of cells occur in liquid media. Creeping motility on solid surfaces, non-motile in liquids.

Growth on a sea water-peptone agar plate begins as a thin, pink, rapidly spreading swarm which often covers the entire surface in a few days. The swarm gradually increases in thickness and develops an irregular, beaten-copper surface due to the liquefaction of the underlying agar. After 4 to 5 days the color becomes orange. Liquefaction of the agar is ultimately almost complete.

Sea water-gelatin stab: Rapid liquefaction.

Growth in liquid media is turbid, often with suspended floccules and a heavy pellicle.

Xylose, glucose, galactose, lactose, maltose, cellobiose, cellulose, agar and alginic acid are utilized, but not arabinose, sucrose, chitin or starch.

Yeast extract and peptone are the only suitable nitrogen sources known.

Weakly catalase positive.

Indole not formed.

Nitrites produced from nitrates.

Hydrogen sulfide not produced.

Salt concentration range: 1.5 to 5.0 per cent.

Slightly aerobic.

Optimum temperature 22° to 25°C.

Source: Isolated from sea water.

Habitat: Sea water. Probably on decaying marine vegetation.

10. **Cytophaga sensitiva** Humm. (Duke Univ. Marine Lab., North Carolina, Bull. 3, 1946, 64.) Etyomology: Latin *sensus*, to perceive.

Cells long, slender, flexous rods. Apparently not flagellated, 0.8 to 1.0 by 7.0 to 20 microns. Cell ends not tapered or only slightly so. Gram-negative. Cells exhibit creeping motility on agar with ability to reverse direction of movement without turning. Bending movements occur in liquid media.

Colonies light orange, thin and shining. Irregular margin. Outer part composed of a single layer of cells, spreading rapidly, the center somewhat thicker and more or less opaque, sunken in the agar. Agar liquefied. Single colony may nearly cover the surface of the agar in the Petri dish within one week; center of colony sinks to the bottom of the dish and may develop vertical sides. Usually the colony begins to die after a week or ten days from the center outward, as shown by loss of pigment. Apparently no water-soluble pigment is produced. Colony 18 mm in diameter and gelase field 25 mm in diameter after three days on agar containing 0.8 per cent potassium nitrate and 0.8 per cent peptone (iodine stain).

Gelatin: No growth.

Milk: No growht.

Nitrate apparently not produced from nitrate (agar medium).

Optimum nitrate concentration of medium appeared to be 0.5 per cent. Fair growth on sea water plus agar only, and on agar containing 1.0 per cent potassium nitrate. Slight growth on 2.0 per cent nitrate agar.

Optimum peptone concentration appeared to be about 0.1 per cent; growth inhibited by concentrations of peptone exceeding 0.4 per cent.

No growth on agar media containing any one of the following substances in a concentration of 0.2 per cent glucose, starch, ammonium sulfate. The basal medium, however, supported excellent growth.

Repeated efforts were made to obtain a pure culture by streaking plates and by pouring plates. These were finally suc-

cessful by the use of an agar medium that contained 0.1 per cent peptone, 0.05 per cent beef extract, 0.05 per cent glucose, and traces of yeast extract and ferric phosphate. Good growth on broth of this composition was also obtained. Apparently the yeast extract supplied necessary growth substances.

Source: Isolated September 19, 1945 from a mixed culture with *Pseudomonas corallina*, by streaking a piece of *Dictyota dichotoma* on agar containing 0.2 per cent potassium nitrate.

Habitat: From seaweed. Beaufort, North Carolina.

Appendix: Stapp and Bortels (Cent. f. Bakt., II Abt., *90*, 1934, 28) described four new obligate cellulose-decomposing species: *Cytophaga silvestris*, *Cytophaga anularis*, *Cytophaga flavicula* and *Cytophaga crocea*. The differences between them are small and, while it is impossible to make positive identifications on the basis of present knowledge, they seem to be very similar to *Cytophaga hutchinsonii*. In the absence of comparative pure culture studies on the obligate cellulose-decomposing members of the genus, the proper delimination of species is not possible. Their inclusion in keys must await additional information.

FAMILY II. ARCHANGIACEAE JAHN.

(Beiträge zur botan. Protistologie, I. Die Polyangiden. Geb. Borntraeger, Leipzig, 1924.)

In the organisms belonging to this family the swarm (pseudoplasmodium) produces irregular swollen or twisted fruiting bodies, or develops columnar or finger-like growths, usually without a definitely differentiated membrane.

Key to the genera of family **Archangiaceae.**

I. Fruiting body depressed, usually irregularly delimited, the interior usually consisting of swollen or intestine-like twisted or inter-twined masses, whose windings may be constricted or may jut out (project) as free ends.

Genus I. *Archangium*, p. 1017.

II. Fruiting body consists of single (separate) columnar or finger-like structures arising from the substrate.

Genus II. *Stelangium*, p. 1020.

Genus I. **Archangium** *Jahn.*

(Jahn, Beiträge zur botan. Protistologie, I. Die Polyangiden. Geb. Borntraeger, Leipzig, 1924, 67; *Ophiocystia* Enderlein, Bermerkungen zur Systematik der Chondromyciden, Berlin, 1924, 6 pp.)

Etymology: Greek *arche*, primitive, and *angion*, vessel (according to Jahn, this genus is the most primitive).

The mass of shortened rods embedded in slime forms a pad-shaped or more rounded, superficially swollen or tuberous fruiting body, even with horny divisions. The fruiting body has no membrane. In the interior can be seen a mass resembling coiled intestines. The windings of this coil may be uniform, or irregularly jointed, free or stuck together; the ends may be extended and horny. Instead of a membrane there may be loosely enveloping slime.

The type species is *Archangium gephyra* Jahn.

Key to the species of genus **Archangium.**

I. No slimy capsules.
  A. Fruiting body usually wound, irregularly constricted, sometimes swollen and vesicular, appressed.
    1. Fruiting body red.
      a. The shortened rods 2.5 to 3 microns.
        1. *Archangium gephyra.*
      aa. The shortened rods 4 to 6 microns.
        2. *Archangium primigenium.*
    2. Fruiting body yellow.
        3. *Archangium flavum.*
  B. Tube usually uniformly thick, loosely wound, often branched.
        4. *Archangium serpens.*

II. Fruiting body consisting of a reddish coiled tube, embedded in yellow slime.
        5. *Archangium thaxteri.*

1. **Archangium gephyra** Jahn. (*Chondromyces serpens* Quehl, Cent. f. Bakt., II Abt., *16*, 1906, 16; Jahn, Beiträge zur botanischen Protistologie. I. Die Polyangiden, Geb. Borntraeger, Leipzig, 1924, 67.)

Etymology: Greek *gephyra*, a bridge. So named because a transition form between the *Archangiaceae* and the *Myxococcaceae*.

Swarm stage (pseudoplasmodium): Grows easily in manure decoction, forming a pseudoplasmodium and ring of fruiting bodies. The vegetative rods are about 10 microns long, 0.5 micron in diameter.

Fruiting bodies: Up to 1 mm in diameter, of irregular form and with swollen or padded surface. Average sized fruiting bodies are a reddish flesh color by reflected light; smaller fruiting bodies, a light rose. On a dark background large fruiting bodies when fresh appear bluish violet. By transmitted light the fruiting bodies appear yellowish to light red. Upon addition of alcohol or when heated in glycerine, they lose the color quickly and appear gray or colorless.

The inner structures are for the most part a mesenteric mass of tubes 40 to 60 microns wide, without any membrane, and without any enclosing slime. The convolutions are often pressed together. On the inside of these tubes there appears definitely a septation by straight or slightly arched cross walls which, however, do not always cut entirely through the spore masses from one side of the tube to the other. Upon pressure, the fruiting body breaks up into a number of small fragments about 15 to 30 microns in diameter. Within these fragments the shortened rods lie parallel and in bundles.

The rods in the fruiting bodies are so shortened that they resemble the spores of the *Myxococcaceae*. The spores are 2.5 to 2.8 microns long and about 1.4 microns wide. Often they are somewhat bent so that they appear to be bean-shaped. In the smooth, transparent tips of fruiting bodies they stand closely parallel to each other, so that in transmitted light one sees only their cross section and is at first led to believe that he is dealing with one of the *Myxococcaceae*.

Source and habitat: Found frequently in the region of Berlin on the dung of deer, rabbits, and hare, once also on old decaying lichens. Easily overlooked on account of its usual bluish color. According to Krzemieniewski (1927) the most common of myxobacteria in the soils of Poland. Isolated on rabbit dung.

Illustrations: Quehl (*loc. cit.*) Pl. 1, Fig. 7. Jahn (1924, *loc. cit.*) Pl. 1, Fig. 5. Krzemieniewski, Acta Soc. Bot. Poloniae, *4*, 1926, Pl. III, Figs. 25–26.

2. **Archangium primigenium** (Quehl) Jahn. (*Polyangium primigenium* Quehl, Cent. f. Bakt., II Abt., *16*, 1906, 16; Jahn, Beiträge zur botanischen Protistologie. I. Die Polyangiden, Geb. Borntraeger, Leipzig, 1924.)

Etymology: Latin, *primigenius*, primitive, referring to the simple and primitive character of the fruiting body.

Swarm stage (pseudoplasmodium): In manure decoction cysts germinate readily. Vegetative rods 4 to 8 microns in length.

Fruiting bodies: Up to 1 mm in diameter, sometimes larger, with irregularly padded swollen surface; when fresh a lively red color which is quite prominent especially against a dark background; when dried, dark red. In transmitted light flesh red to yellowish red. In alcohol and upon heating it is quickly bleached.

In transmitted light one sees that the fruiting body is made up of numerous intestine-like convolutions closely appressed, not however, always definitely delimited. These tubes usually have a diameter of from 70 to 90 microns, often constricted and attenuated. No membrane is present. The rods in the fruiting bodies are about 4 microns long and 0.8 micron wide. Upon pressure on the fruiting bodies, the rods remain together in small fragments of various sizes.

2a. *Archangium primigenium* var.

assurgens Jahn. (Jahn, Beiträge zur botanischen Protistologie. I. Die Polyangiden, Geb. Borntraeger, Leipzig, *5*, 1924, 69; *Archangium assurgens* Krzemieniewski, Acta Soc. Bot. Poloniae, 1927, 95.)

Etymology: Latin *assurgens*, rising up.

Size and color of the fruiting body as in the species, likewise the inner structure, size and arrangement of the rods. However, the tubules which together constitute the fruiting bodies are more or less free at their ends and stand up from the substrate. Their diameter is somewhat less (about 45 microns), they are often convoluted so that they many times appear to be constricted (like pearls).

Pronounced races of the species and of the variety are so different in habits that they may be regarded as distinct species. Jahn believes the presence of intermediate strains makes a separation difficult.

Source and habitat: According to Jahn, *Archangium primigenium* is not particularly common. It is usually found on rabbit dung, sometimes.on roe dung. The variety *assurgens* is relatively rare (found three times on rabbit dung) Kofler (1930) on rabbit dung, Vienna. Very rare in Polish soils according to Krzemieniewski (1927).

Illustrations: Quehl, Cent. f. Bakt., II Abt., *16*, 1906, 16, Pl. 1, Fig. 5; Jahn, Kryptogamenflora d. Mark Brandenburg, V, Pilze I, Lief. 2, 1911, 201, Pl. 1, Fig. 5; Jahn (1924, *loc. cit.*) Pl. 1, Fig. 4, also Fig. G, page 37; Krzemieniewski (1926, *loc. cit.*) Pl. II, Fig. 23; (1927, *loc. cit.*) Pl. IV, Fig. 3. var. *assurgens*, Pl. IV, Fig. 1 and 2.

3. **Archangium flavum** (Kofler) Jahn. (*Polyangium flavum* Kofler, Sitzber. d. Kais. Akad. Wiss. Wien. Math.-Nat. Klasse, 122 Abt., 1913, 864; Jahn, Beiträge zur botanischen Protistologie. I. Die Polyangiden, Geb. Borntraeger, Leipzig, 1924, 71.)

Etymology: Latin *flavus*, golden or reddish-yellow.

Swarm stage (pseudoplasmodium): Not described.

Fruiting bodies: About 0.5 mm in diameter, yellow, spherical or oval, with humped or padded surface. The mass of cells quite homogeneous, upon pressure under cover glass single sections tend to adhere. No membrane, though the rods are so tightly linked that when cautiously placed under a cover glass, the form of the fruiting body is retained. Rods 2 to 4 microns.

Source and habitat: Kofler (1924) on hare dung found in Danube meadows. Reported as frequent in Polish soils by Krzemieniewski (1926, 1927).

Illustrations: Krzemieniewski, Acta Soc. Bot. Poloniae, *4*, 1926, Pl. II, Fig. 24. (1927), Pl. IV, Fig. 4, 5 and 6.

4. **Archangium serpens** (Thaxter) Jahn. (*Chondromyces serpens* Thaxter, Bot. Gaz., *17*, 1892, 403; Jahn, Beiträge zur botanischen Protistologie. I. Die Polyangiden, Geb. Borntraeger, Leipzig, 1924, 72.)

Etymology: Latin *serpens*, creeping.

Swarm stage (pseudoplasmodium): Rods cylindrical, 0.6 by 5 to 7 microns. Cultures on agar develop convoluted form.

Fruiting body: About 1 mm in diameter, recumbent, consisting of numerous loosely intertwined cysts, confluent in an anastomosing coil, flesh-colored, when dry dark red, 50 microns in diameter, bent, occasionally somewhat broadened or constricted, branched.

Source and habitat: Thaxter, Bot. Gaz., *17*, 1892, 389. On decaying lichens. Cambridge, Mass.

Illustrations: Thaxter (*loc. cit.*), Pl. 24, Fig. 24.

5. **Archangium thaxteri** Jahn. (Beiträge zur botanischen Protistologie. I.

Die Polyangiden, Geb. Borntraeger, Leipzig, 1924, 71.)

Etymology: Named for Dr. Roland Thaxter.

Swarm stage (pseudoplasmodium): Vegetative stages not observed. Either no germination or prompt cessation of growth on dung extract. May be transferred on dung.

Fruiting body: Usually 0.25 to 0.5 mm, occasionally 0.75 mm in diameter. Irregularly rounded, superficially sulfur yellow. Upon pressure numerous reddish convoluted tubules are observed embedded in a yellow slime. The average diameter of the tubules is about 50 microns. No membrane surrounds the tubes. They contain the shortened rods. The fruiting body is bleached by alcohol or heat, becoming yellowish. Enveloping slime is variable. In well developed specimens the slime forms a stalk, giving the whole the appearance of a morel. In small specimens the rods are embedded in the slime. The fruiting bodies stand loosely separated on surface of dung, never in large groups. Shortened rods (spores) 0.5 micron by 3 microns, very slender.

Source and habitat: According to Jahn rare, on rabbit dung. Races with well developed stalks even less common.

Illustrations: Jahn (*loc. cit.*), Pl. 1, Fig. 1 and 2. Krzemieniewski, Acta Soc. Bot. Poloniae, *4*, 1926, Pl. II, Fig. 27.

Genus II. **Stelangium** *Jahn.*

(Kryptogamenflora der Mark Brandenburg, V, Pilze I, Lief. 2, 1911, 205.)

Etymology: Greek *stele*, pillar or column and *angion*, vessel.

Diagnosis: Fruiting bodies are columnar or finger-like, sometimes forked, without definite stalk, standing upright on the substrate.

The type species is *Stelangium muscorum* (Thaxter) Jahn.

1. **Stelangium muscorum** (Thaxter) Jahn. (*Chondromyces muscorum* Thaxter, Bot. Gaz., *37*, 1904, 411; Jahn, Kryptogamenflora der Mark Brandenburg, V, Pilze I, Lief. 2, 1911, 205.)

Etymology: Latin *muscus*, moss.

Swarm stage (pseudoplasmodium): Not described.

Fruiting body: Bright yellow-orange, 90 to 300 microns long, 10 to 50 microns wide, without differentiated stalk, simple or rarely furcate, upright, elongate, compact or slender, narrowed at tip. Rods (spores) 1 to 1.3 by 4 to 6 microns.

Source and habitat: According to Thaxter (*loc. cit.*) on liverworts on living beech trunks in Indiana.

Illustrations: Thaxter (*loc. cit.*) Pl. 27, Figs. 16–18.

FAMILY III. SORANGIACEAE JAHN.

(Beiträge zur botan. Protistologie. I. Die Polyangiden. Geb. Borntraeger, Leipzig, 1924, 73.)

Diagnosis: The shortened rods of the fruiting body lie in angular, usually relatively small cysts of definite polygonal shape. Often many of these cysts are surrounded by a common membrane. The primary cyst may be differentiated from the angular or secondary cysts. No stalked forms are known.

Genus I. **Sorangium** *Jahn.*

(Jahn, Beiträge z. botan. Protistologie. I. Die Polyangiden. Geb. Borntraeger, Leipzig, 1924, 73; *Cystoecemia* Enderlein, Bemerkungen z. Systematik d. Chondromyciden, Berlin, 1924, 73.)

Etymology: Greek *soros*, heap and *angion*, vessel.

Diagnosis: As for the family. The cysts are united into rounded fruiting bodies. Eight species have been allocated to this genus.

The type species is *Sorangium schroeteri* Jahn.

Key to the species of Genus **Sorangium.**

I. Fruiting bodies not black when ripe.
  A. Primary cysts absent; fruiting body shows only angular, spherical or oval small cysts.
    1. Cysts angular.
      a. Fruiting body very small (50 to 80 microns), often irregularly cerebriform; the angular cysts often completely separated from each other, and about 13 microns in diameter.
        1. *Sorangium schroeteri.*
      aa. Fruiting body composed of many small cysts.
        b. Cysts orange-red in color; over 5.0 microns in diameter.
          2. *Sorangium sorediatum.*
        bb. Rusty brown color; cysts less than 3.5 microns in diameter.
          3. *Sorangium cellulosum.*
    2. Cysts spherical or oval.
      4. *Sorangium spumosum.*
  B. Both primary and secondary cysts present.
    1. Primary cysts small and numerous, about 20 microns, with definite membrane and few angular secondary cysts.
      5. *Sorangium septatum.*
    2. Primary cysts large, with delicate, often indefinite, membrane.
      6. *Sorangium compositum.*
II. Fruiting bodies black or brownish-black when ripe.
  A. Primary cysts generally not formed.
    7. *Sorangium nigrum.*
  B. Primary cysts generally formed.
    8. *Sorangium nigrescens.*

1. **Sorangium schroeteri** Jahn. (Jahn, Beiträge zur botanischen Protistologie. I. Die Polyangiden. Geb. Borntraeger, Leipzig, 1924, 73; regarded as a synonym

of *Sorangium compositum* by Krzemieniewski, Acta Soc. Bot. Poloniae, *5*, 1927, 96.)

Etymology: Named for Julius Schroeter (1837–1894).

Swarm stage (pseudoplasmodium): Not described.

Fruiting bodies: Very small, circular, swollen, often kidney-shaped with brain-like convolutions, usually 60 microns (occasionally 120 microns) in diameter, bright orange-red. Surrounded by a delicate slime membrane about 0.7 micron thick, apparent only with high magnifications. Divided secondarily into angular cysts, by sutures extending inward which divide the mass regularly into well delimited portions, many angled, usually about 12 microns in diameter, and in other places into areas less well delimited and about 14 microns in diameter. Resembles gelatin which has dried in a sheet and cracked into regular areas. Rods in cysts 5 microns long. Cysts sometimes occur together in large numbers, covering an area to 0.5 mm.

Source and habitat: Found by Jahn (*loc. cit.*) five times on rabbit dung in environs of Berlin.

Illustrations: Jahn (1924, *loc. cit.*), Pl. 2, Fig. 22.

2. **Sorangium sorediatum** (Thaxter) Jahn. (*Polyangium sorediatum* Thaxter, Bot. Gaz., *37*, 1904, 414; Jahn, Beiträge zur botanischen Protistologie. I. Die Polyangiden, Geb. Borntraeger, Leipzig, 1924, 73.)

Etymology: From Greek, *soros*, heap, probably through the botanical term soredium, one type of reproductive body in the lichen, and sorediate, with surface patches like soredia.

Swarm stage (pseudoplasmodium): Rods 0.8 by 3 to 5 microns. Attempts to cultivate have failed.

Fruiting body: Orange-red, irregularly lobed, consisting of a compact mass of small angular cysts. Average size of cysts 6 to 7 microns, smallest 3 microns, with thick and sharply defined edges. Rods 0.8 by 3 to 5 microns. The Krzemieniewskis (1927, *loc. cit.*, 96) have described a variety, *Sorangium sorediatum* var. *macrocystum*, consisting of cysts 6 to 14 by 7 to 16 microns, about twice as large as in the type.

Source and habitat: Reported once by Thaxter (*loc. cit.*) on rabbit dung from South Carolina. Krzemieniewski (1927, *loc. cit.*) common in Polish soils.

Illustrations: Thaxter (*loc. cit.*) Pl. 27, Figs. 22–24. Quehl, Cent. f. Bakt., II Abt., *16*, 1906, 9, Pl. 1, Fig. 2. Jahn, Kryptogamen-flora d. Mark Brandenburg, V, Pilze I, Lief. 2, 1911, 202, Fig. 1. Krzemieniewski, Acta Soc. Bot. Pol., *4*, 1926, Pl. IV, Figs. 39–41. (1927, *loc. cit.*) Pl. V, Fig. 17, var. *macrocystum* Fig. 18.

3. **Sorangium cellulosum** Imšenecki and Solntzeva. (Microbiology, Moscow, *6*, 1937, 7.)

Etymology: Modern Latin *cellulosum*, cellulose.

Fruiting body: Mature fruiting body rusty brown, 400 to 500 microns in diameter, sessile on layer of partially dried slime. No outer wall or limiting membrane. Composed of numerous cysts, irregular in shape, 1.6 to 3.2 microns in diameter, each containing less than ten shortened rods. No discernable cyst wall or membrane.

Spores: 0.3 by 1.5 to 2.0 microns (no other data).

Vegetative cells: Flexible, rod-shaped cells with rounded ends, occurring singly; no flagella but motile by means of a crawling motion; 0.4 to 0.6 by 2.2 to 4.5 microns.

Vegetative colony: No data.

Physiology: Good growth on starch, cellulose. Decompose up to 24 per cent cellulose in ten days, but does not form fruiting bodies. Very poor growth on arabinose with formation of many involution forms including very much elongated

cells. Fail to grow on nutrient agar, washed agar, potato, carrot, milk.

Source: Isolated from soil.

Habitat: Soil. Decomposes organic matter.

4. **Sorangium spumosum** Krzemieniewski and Krzemienewska. (Acta Soc. Bot. Poloniae, *5*, 1927, 97.)

Etymology: Latin *spumosus*, frothy or foamy.

Swarm stage (pseudoplasmodium): Rods 0.7 to 0.9 by 2.6 to 5.2 microns.

Fruiting bodies: Consist of numerous cysts, spherical or oval, not surrounded by a common membrane, but united into bodies embedded in slime. Often in double or single rows. Cyst walls colorless, or slightly brownish, transparent, so that the characteristic arrangement of the rods may be seen within. Cysts 8 to 26 by 7 to 20 microns.

Source and habitat: Krzemieniewski (1927, *loc. cit.*) from Polish soil, isolated on rabbit dung.

Illustrations: Krzemieniewski (1927, *loc. cit.*) Pl. V, Fig. 19.

5. **Sorangium septatum** (Thaxter) Jahn. (*Polyangium septatum* Thaxter, Bot. Gaz., *37*, 1904, 412; Jahn, Beiträge zur botanischen Protistologie. I. Die Polyangiden, Geb. Borntraeger, Leipzig, 1924, 75.)

Etymology: Latin *saeptatus*, fenced, *i.e.*, divided by walls.

Swarm stage (pseudoplasmodium): Rods 0.8 to 1 by 3 to 5 microns.

Fruiting bodies: Yellowish-orange. When dried, dark orange-red, 50 microns to more than 100 microns in diameter, cysts rounded or ovoid, angular or cylindrical, inner portion of the envelope divided into a variable number of secondary cysts. Cysts 18 to 22 by 12 to 22 microns in diameter. Secondary cysts 10 to 12 microns. The Krzemieniewskis (1927, *loc. cit.*, 96) recognize a variety, *Sorangium septatum* var. *microcystum*, which has secondary cysts with dimensions 4 to 10 by 3 to 8 microns.

Source and habitat: Collected twice (Thaxter, Bot. Gaz., *37*, 1904, 412) on horse dung in Cambridge, Mass. Reported by Krzemieniewski (Acta Soc. Bot. Poloniae, *5*, 1927) as common in Polish soil.

Illustrations: Thaxter (*loc. cit.*) Pl. 27, Figs. 25–28. Jahn, Kryptogamen-flora d. Mark Brandenburg, V, Pilze I. Lief 2, 1911, 202, Fig. 2. Krzemieniewski, Acta Soc. Bot. Pol., *4*, 1926, Pl. 27, Figs. 27–38; *ibid.*, 1927, Pl. V, Fig. 15, var. *microcystum*, Fig. 16.

6. **Sorangium compositum** (Thaxter) Jahn. (*Polyangium compositum* Thaxter, Bot. Gaz., *37*, 1904, 413; Jahn, Beiträge zur botanische Protistologie. I. Die Polyangiden, Geb. Borntraeger, Leipzig, 1924, 74; *Polyangium sorediatum* Quehl, Cent. f. Bakt., II Abt., *16*, 1906, 17; not *Polyangium sorediatum* Thaxter, *ibid.*)

Etymology: Latin *compositus*, compound.

Swarm stage (pseudoplasmodium): Not described.

Fruiting bodies: Dull yellowish-orange changing to dark red on drying. Rounded, small, 0.5 to 1 mm, usually as a whole or even in larger clumps surrounded by a delicate and evanescent membrane. In large fruiting bodies the cysts are bound together in balls 70 to 90 microns in diameter by a delicate membrane. The balls readily fall apart. Secondary cysts are angular, 7 by 11 microns, surrounded by a delicate orange-red membrane, about 0.4 micron in thickness. Length of rods in the cysts 5 microns.

Source and habitat: Thaxter (*loc. cit.*) rabbit dung, South Carolina. Jahn (1904, *loc. cit.*) found it four times on rabbit dung near Berlin, and twice on hare dung in Oberharg. Common in soils of Poland according to Krzemieniewski (1927, *loc. cit.*).

Illustrations: Thaxter (*loc. cit.*) Pl. 27, Figs. 29-30. Jahn (1924, *loc. cit.*) Pl. I, Fig. 6. Krzemieniewski, Acta Soc. Bot. Pol., *4*, 1926, Pl. III, Figs. 32-36; *ibid.*, 1927, *5*, Pl. IV, Figs. 7, 8, 9, 10, 11, 12; Pl. V, Figs. 13, 14; Pl. VI, Fig. 36.

7. **Sorangium nigrum** Krzemieniewski. (Bull. Int. l'Acad. Pol. Sci. et Lettres, Classe Sci. Math. et Nat., Sér. B, *15*, 1937.)

Etymology: Latin *niger*, black.

Fruiting body: Primary cysts generally not formed; when observed, appeared as smoke-colored slime envelope surrounding clumps of a few cysts. Secondary cysts usually arranged in rows within cellulose fibers, the material of the fiber forming a common sheath. Each individual cyst inclosed by a cyst wall, clearly differentiated from the tubular-shaped cellulose fibers. Cysts measure 9 to 16 by 9 to 23 microns; average 10 by 18 microns. Cyst wall moderately thick, colorless, transparent, becoming light brown with age, and finally black.

Spores: No data.

Vegetative cells: 1.1 to 1.3 by 2.5 to 5.5 microns.

Vegetative colony: Young colonies dead black in color. On filter paper a bright orange margin is noted, the vegetative cells of which cover the cellulose fibers. On cotton cloth the margin is bright dirty-yellow, tinged with pink. Under low power magnification, center of the colony appears similar to matted fungal hyphae, due to characteristic compact accumulation of cysts and cellulose fibers.

Physiology: Cellulose fibers become swollen by the action of this organism, and become gray-brown with a violet tinge. Fibers lose the properties of cellulose and give no characteristic reactions.

Source: Isolated from soil.

Habitat: Soil. Decomposes cellulose fibers.

Illustrations: Krzemieniewski (*loc. cit.*) Plate IV, Figs. 22-26.

8. **Sorangium nigrescens** Krzemieniewski. (Bull. Int. l'Acad. Pol. Sci. et Lettres, Classe Sci. Math. et Nat., Sér. B, *15*, 1937.)

Etymology: Latin *nigrescens*, becoming dark or black.

Fruiting body: Primary cysts vary in size up to 200 microns in diameter, irregular in shape and inclosed in a colorless slime envelope. Formed by an accumulation of secondary cysts. Secondary cysts at first colorless, transparent, later becoming brownish with a limiting membrane; the young cysts appear dirty-yellow, the older ones grayish-brown to black. Color originates not only from the brownish cyst wall but from the gray mass of encysted cells. Secondary cysts measure 5 to 12 by 6 to 15 microns; average 6 by 10 microns. On filter paper not only well-formed primary cysts are formed, but also free secondary cysts are noted embedded in the slime of the colony.

Spores: No data.

Vegetative cells: 1.2 to 1.4 by 2.5 to 6.4 microns. Younger cells somewhat shorter.

Vegetative colony: Mass of dark fruiting bodies develops at center of colony on filter paper; margin grayish-yellow. Cellulose fibers covered with vegetative cells on outside, and contain many cells within.

Physiology: Destroys cellulose. Cultivated six years with cellulose as carbon source.

Source: Isolated from sandy soil in pine woods in Ciemianka (?).

Habitat: Soil. Decomposes cellulose fibers.

Illustrations: Krzemieniewski (*loc. cit.*) Plate III, Figs. 17-21.

FAMILY IV. POLYANGIACEAE JAHN

(Beiträge zur botan. Protistologie. I. Die Polyangiden. Geb. Borntraeger, Leipzig, 1924.)

Diagnosis: In the fruiting bodies the more or less shortened rods lie in rounded cysts of definite form. The well-defined wall is composed of hardened slime, and is yellow, red or brownish. The cysts may be united by a definitely visible slime membrane, the remnant of the vegetative slime, or they may be tightly appressed and cemented by the scarcely visible remnants of the slime, or they may develop singly or in numbers on a stalk. In the more highly developed forms the stalk branches and carries the cysts at the tips of the branches.

Key to the genera of family **Polyangiaceae.**

I. Cysts rounded, not stalked, usually many (one in *Polyangium simplex*) lying loosely in a slime membrane or closely appressed.
   Genus I. *Polyangium*, p. 1025.

II. Cysts not as in I.
   A. Cysts pointed at the apex, often completely concrescent, and united to large disks or spheres.
      Genus II. *Synangium*, p. 1032.
   B. Cysts free, single or many on a stalk.
      1. Cysts forming a disk, flattened dorsoventrally, like the cap of a *Boletus*, on a white stalk.
         Genus III. *Melittangium*, p. 1033.
      2. Cysts not forming a disk.
         a. Cysts rounded or elongate, single on stalks.
            Genus IV. *Podangium*, p. 1034.
         aa. Cysts rounded or elongate or pointed, numerous on the ends of stalks which may be branched.
            Genus V. *Chondromyces*, p. 1036.

Genus I. **Polyangium** *Link.*

(Link, Mag. d. Ges. Naturforsch. Freunde zu Berlin, *3*, 1809, 42; *Cystobacter* Schroeter, in Cohn, Kryptogamenflora v. Schlesien, *3*, 1, 1886, 170; *Myxobacter* Thaxter, Bot. Gaz., *17*, 1892, 394.)

Etymology: Greek *poly*, many and *angion*, vessels, referring to the numerous cysts.

Diagnosis: Cysts rounded or coiled, surrounded by a well-developed membrane, either free or embedded in a second slimy layer.

The type species is *Polyangium vitellinum* Link.

Key to the species of genus **Polyangium.**

I. Not parasitic on water plants (algae).
   A. Sorus not white or grayish in color.
      1. Cysts rounded to spherical.
         a. Ripe cysts yellow, reddish-yellow, orange or light red; not brown.
            b. Cysts several or numerous and small.
               c. Not closely appressed.
                  d. Slime envelope transparent white or colorless.
                     e. Usually 10 to 15 cysts. Rods in cysts, 3 microns long. Cysts 75 to 200 microns.
                        1. *Polyangium vitellinum.*

ee. Cysts numerous. Rods 1.3 to 2.0 microns long. Cysts 20 to 80 microns.
2. *Polyangium minus.*
dd. Slime envelope bright yellow.
3. *Polyangium luteum.*
cc. Closely appressed; often polygonal due to pressure.
d. Bright yellow.
4. *Polyangium morula.*
dd. Orange.
5. *Polyangium cellulosum.*
bb. Cysts single, large.
c. Large, 250 to 400 microns; reddish-yellow.
6. *Polyangium simplex.*
cc. Smaller, 30 to 60 by 50 to 130 microns; orange to light red.
7. *Polyangium ochraceum.*
aa. Ripe cysts reddish-brown to dark brown.
b. Cysts lying free, covered by a more or less definite slime envelope.
c. About 60 microns in diameter; slime envelope delicate and colorless.
8. *Polyangium fuscum.*
cc. About 35 microns in diameter; slime envelope yellow.
9. *Polyangium aureum.*
bb. Cysts rounded, in stellate arrangements on a slimy substrate.
10. *Polyangium stellatum.*
2. Cysts elongate, coiled.
a. Cysts brownish-red.
11. *Polyangium ferrugineum.*
aa. Cysts bright orange-yellow.
12. *Polyangium indivisum.*
B. Sorus white or gray in color.
1. Hyaline slime envelope white, foamy in appearance; cysts average 28 by 34 microns.
13. *Polyangium spumosum.*
2. Sorus flat, crust-like, smoke-gray in color due to slime envelope; cysts average 36 by 44 microns.
14. *Polyangium fumosum.*
II. Aquatic, parasitic on *Cladophora.*
15. *Polyangium parasiticum.*

1. **Polyangium vitellinum** Link. (Link, Mag. d. Ges. Naturforschender Freunde zu Berlin, *3*, 1809, 42; *Myxobacter aureus* Thaxter, Bot. Gaz., *17*, 1892, 403.)

Etymology: Modern Latin *vitellus*, like an egg yolk.

Swarm stage (pseudoplasmodium): When rising to form cysts, milky white. Rods large, cylindrical, rounded at either end, 0.7 to 0.9 by 4 to 7 microns.

Fruiting body: Cysts golden yellow, usually relatively spherical, 75 to 150 microns, occasionally 200 microns in diameter, almost always surrounded by a white slimy envelope, about 10 to 15 cysts in a mass. Rods in the cysts about 3 microns in length.

Source and habitat: Thaxter (*loc. cit.*) on very wet wood and bark in swamps. Maine, Belmont. Jahn (1924, *loc. cit.*) states it is not common; on old wood, lying in moist ditches, also on old poplar bark which was kept moist in a dish, also found twice on rabbit dung.

Illustrations: Thaxter (*loc. cit.*) Pl.

25, Figs. 34–36. Zukal, Ber. d. deutsch. Bot. Ges., *15*, 1897, 542, Pl. 27, Figs. 6–10. Jahn, Kryptogamenflora d. Mark Brandenburg, V, Pilze I, Lief. 2, 1911, 199, Fig. 3. Jahn, Beiträge zur botanischen Protistologie. I. Die Polyangiden. Geb. Borntraeger, Leipzig, 1924, 77, and Pl. II, Fig. 13.

2. **Polyangium minus** Krzemieniewski. (Acta Soc. Bot. Poloniae, *4*, 1926, 33.)

Etymology: Latin *minor*, less or small.

Swarm stage (pseudoplasmodium): Vegetative rods 0.4 to 0.6 by 3 to 7 microns.

Fruiting bodies: Cyst masses commonly cover the substrate to an area of 0.5 sq. mm. Cysts are spherical or oval, small, 20 to 80 by 20 to 50 microns, light rose in color, becoming brownish, embedded in a transparent colorless slime. Cyst membrane light colored, relatively thick, 0.5 to 1.0 micron, transparent, revealing the contents. Rods in cyst 0.8 to 1.0 by 1.3 to 2.0 microns.

Source and habitat: On rabbit dung sterilized and placed on soil (Poland). Rather rare. Relatively slow in appearance, only after many days.

Illustrations: Krzemieniewski (*loc. cit.*) Pl. IV, Fig. 47–48; Pl. V, Fig. 49.

3. **Polyangium luteum** Krzemieniewski. (Acta Soc. Bot. Poloniae, *5*, 1927, 98.)

Etymology: Latin *luteus*, saffron- or golden-yellow.

Swarm stage (pseudoplasmodium): Not described.

Fruiting bodies: Golden yellow, consisting of a few cysts surrounded by a common bright yellow very thick slime wall. The cysts have colorless thin walls. Rods 0.7 to 0.8 by 3.8 to 5.8 microns.

Source and habitat: Isolated from soil on rabbit dung by Krzemieniewski (1927).

Illustration: Krzemieniewski (*loc. cit.*) Pl. V, Fig. 22, 23.

4. **Polyangium morula** Jahn. (Kryptogamenflora der Mark Brandenburg., V, Pilze I, 1911, 202.)

Etymology: Modern Latin from Greek *mōra*, mulberry. A diminutive referring to shape of cysts.

Swarm stage (pseudoplasmodium): Not described.

Fruiting bodies: Cysts bright yellow, closely packed into a mulberry-shaped sorus; cysts with thick membrane (3 microns), often made polygonal by pressure, 20 to 35 microns, bound together by slime. The whole sorus is 100 to 200 microns broad. Rods in cysts about 3 microns in length. Jahn states he has not studied fresh cysts. In the older cysts the rods are difficult to observe.

Source and habitat: Observed once only by Jahn (*loc. cit.*) on rabbit dung.

Illustration: Jahn (1924, *loc. cit.*) Pl. 2, Fig. 21.

5. **Polyangium cellulosum** Imšenecki and Solntzeva.* (On aerobic cellulose-decomposing bacteria. Akademiia Nauk, Leningrad, Isvestiia, 1936, 1115; English summary, 1168.)

Etymology: Modern Latin *cellulosum*, cellulose.

Fruiting body: Rods at center of the colony non-motile, forming large orange aggregates. Shorter than those at margin: 0.7 to 0.9 by 3.4 to 5.6 microns. Later a concentration of cells occurs. Rods come closer together, form rounded or oval aggregates from which cysts become delimited. Cysts orange in color, 8 to 24 microns, average 20 to 25 microns. In addition to bacterial cells droplets of fat, 1.5 to 3.5 microns, are sometimes seen within the cyst. When treated with H_2SO_4, cysts are easily broken up under the cover glass. Fruiting bodies are composed of clumps of cysts. Fruiting bodies oval or pear-

* Translated from the original by E. V. Prostov, Iowa State College Library, Ames, Iowa.

shaped, 40 to 55 by 110 to 160 microns, reddish-brown. Covered with a slime membrane (flakes of dried slime). Each composed of 12 to 40 cysts which become polygonal from pressure. No cystophore, except those formed from slimy threads which have a stratified structure. Cysts sometimes arranged in chains.

Spores: 0.7 to 0.8 by 2.2 to 3.5 microns.

Vegetative cells: Thick, bent rods, with rounded ends, 0.8 to 1.2 by 3.5 to 8.5 microns. Motile, no flagella. Young rods have 1 chromatin granule, older have 2. Found in cellulose fibers at the margin of the colony. Fibers solidly stuffed near the margin. At the periphery individual cells may be seen.

Vegetative colony: Cysts germinate on filter paper producing vegetative colonies. Colonies large, orange, moist, increasing in size. The older colonies have orange margins while the center is dark brown, corresponding to the color of the fruiting bodies. Often show several concentric rings.

Physiology: Rods cover cellulose fibers, partially or completely destroying them. Paper becomes transparent.

Optimum temperature 18° to 22°C. At 30° growth very slow.

Grows only on wet cellulose; not in ordinary media. No growth in a hanging drop of broth.

Aerobic.

Source and habitat: Soil.

Illustrations: Imšenecki and Solntzeva (*loc. cit.*) Table II, 2; figures 1 to 5.

5a. *Polyangium cellulosun* var. *ferrugineum* Mishustin. (Microbiology, Moscow, 7, 1938, 427.)

Etymology: Latin *ferrugineus*, of the color of iron-rust.

Fruiting body: Composed of numerous cysts having definite wall. Mass of rods has a yellowish tinge, and the cysts are colored reddish-yellow. Color probably confined to the cyst walls. Cysts round or egg-shaped, or may be angular due to pressure. Each cyst contains numerous shortened rods. Cysts usually 12 to 40 microns in diameter. Numerous cysts grouped into fruiting bodies having bright red or drabbish red color when ripe. Form of fruiting body variable: most commonly rounded, ellipsoidal or biscuit-shaped, sometimes sausage-shaped. Cysts confined by an orange-colored slime membrane or envelope. No cystophore present. Fruiting bodies not easily broken up. Vary in size from 80 to 240 microns.

Spores: No data.

Vegetative cells: Long, flexible, non-flagellate cells, motile by crawling, 0.8 to 1.2 by 3.0 to 5.0 microns. Become shortened and highly refractile during fruiting body formation.

Vegetative colony: On silica gel with cellulose at first pale pink. After six days fruiting bodies of red color appear, together with free cysts and many non-encysted shortened rods. Fruiting bodies numerous at center of colony, and later form in concentric rings around center. Margin of colony composed of vegetative cells; periphery pink. Mature colonies 2 to 5 cm in diameter, bright red, becoming drabbish red; pigmentation appears to be confined to limited areas. Surface dull, moist. Margin not definite.

Physiology: Cellulose at center of colony completely destroyed; not entirely broken down under remainder of colony.

The author considers this a color variant of *Polyangium cellulosum* Imšenecki and Solntzeva.

Source: Isolated from the black soils of Eastern European Russia.

Habitat: Digests organic matter in soil.

5b. *Polyangium cellulosum* var. *fuscum* Mishustin. (Microbiology, Moscow, 7, 1938, 427.)

Etymology: Latin *fuscus*, dark, swarthy, dusky, tawny.

Fruiting body: Composed of individual cysts, each with separate cyst wall, and held together by a common slime membrane or envelope. Shortened rod-shaped spores inclosed within the cyst

walls. Cysts forming outside the large masses usually rounded; those within often polygonal or angular. Cysts 5 to 24 microns long, oval or egg-shaped. Encysted cells give cysts granular appearance. Ripe cysts brown to light brown in color; immature, yellow to pink. Fruiting bodies pinkish-yellow when young, becoming brown when ripened. Considerable variation in form: round, oval or sausage-shaped, and from 50 to 80 microns up to several hundred microns. Outer slime envelope often indistinct; no dried slime noticeable between the cysts.

Spores: No data.

Vegetative cells: Identical with those of *Polyangium cellulosum* var. *ferrugineum.*

Vegetative colony: A faint yellow cast on cellulose-silica gel after 2 to 3 days. Becomes yellow-orange to yellow-pink after 6 to 8 days, while center is brownish-gray. Margin pinkish to yellow-pink. Surface dull, moist. As fruiting bodies ripen, colony becomes darker, finally dark brown. Reaches diameter of 2 to 5 cm. Fruiting bodies often arranged in form of pigmented, closely set, concentric rings. Margin of colony not clearly defined. Usually regularly rounded or oval. Cellulose completely destroyed only at center of colony.

Source: Common in black soils of Sumy Experiment Station. Found only once in podzol soils.

Habitat: Digests organic matter in soil.

5c. *Polyangium cellulosum* var. *fulvum* Mishustin. (Microbiology, Moscow, 7, 1938, 427.)

Etymology: Latin *fulvus*, reddish-yellow, gold-colored.

Fruiting body: Rose or pink in color, composed of numerous cysts. Young cysts yellow to yellow-orange, becoming pink, rose or red, or pinkish-yellow. Cysts same shape as others of the species; 6 to 24 microns in diameter, average 10 to 12 microns; contain many short rods. Fruiting bodies vary in shape, often elongated, flagella (?)-shaped (columnar?), up to 20 to 25 by 350 to 450 microns. Also globular, mace-shaped, etc. Usually 25 to 40 by 50 to 80 microns. Cysts inclosed by outer common envelope or slime membrane. Easily broken up mechanically.

Spores: No data.

Vegetative cells: 0.8 to 1.2 by 3.5 to 6.0 microns.

Vegetative colony: On cellulose-silica gel form a hardly visible white (colorless ?) colony at 2 days. After 6 days becomes pink in color. Fruiting bodies first form near center. After 9 to 10 days central area reddish-pink while periphery has yellowish cast. Mature colony 2.5 to 7.5 cm in diameter, pink-orange color, fairly regularly round or oval in shape. Pigmented concentric rings of fruiting bodies.

Physiology: Cellulose entirely destroyed at center of colony and often at other points.

Source: Podzol soils of Timiriazev Agricultural Academy. Seldom in black soils of Sumy Experiment Station.

Habitat: Digests organic matter in soils.

5d. *Polyangium cellulosum* var. *luteum* Mishustin. (Microbiology Moscow, 7, 1938, 427.)

Etymology: Latin *luteus*, saffron-yellow, orange-yellow.

Fruiting body: Poorly organized agglomerations of colorless to yellow cysts inclosing sporulated cells. Cysts regularly egg-shaped to oval, 8 to 20 microns in diameter; predominantly 6 to 10 microns. Matured cysts loosely connected into rounded or elongate masses 40 to 80 by 100 to 150 microns. Ripe fruiting bodies easily pulled apart.

Spores: No data.

Vegetative cells: Similar to others of the species.

Vegetative colony: On cellulose colonies regularly rounded or oval, surface has moist appearance. Yellowish cast 2nd or 3rd day, becoming deeper yellow.

Ochre yellow formations resembling fruiting bodies by 5 to 6 days. Many free cysts at center of colony. Later colony becomes pale dirty-yellow, while periphery remains bright yellow. Sometimes one or two brightly pigmented rings consisting of agglomerations of fruiting bodies are found in older colonies. Mature colonies 1.5 to 3.0 cm in diameter.

Physiology: Filter paper completely destroyed at center of colony. Developed better below pH 7 (around pH 6) than others of the species.

Source: Isolated from soils of the Timiriazev Agricultural Academy. Common in podzol soils.

Habitat: Digests organic matter in soil.

6. **Polyangium simplex** Thaxter. (*Myxobacter simplex* Thaxter, Bot. Gaz., *18*, 1893, 29; Thaxter, Bot. Gaz., *37*, 1904, 414.)

Etymology: Latin *simplex*, simple, i.e., not compound.

Swarm stage (pseudoplasmodium): Rods, large, cylindrical, rounded at either end, 0.7 to 0.9 by 4 to 7 microns.

Fruiting bodies: Cysts single, very large, 250 to 400 microns, bright reddish yellow, irregularly rounded. Rods flesh colored in mass. Upon pressure adhering together in sheaves.

Source and habitat: Found by Thaxter (*loc. cit.*) in U. S. A. on very wet wood and bark in swamps.

7. **Polyangium ochraceum** Krzemieniewski. (Acta Soc. Bot. Poloniae, *4*, 1926, 34.)

Etymology: Modern Latin from Greek *ōchra*, yellow ochre, hence ochraceous.

Swarm stage (pseudoplasmodium): Not described.

Fruiting bodies: The orange to light red fruiting body in form of a single spherical or oval cyst 60 to 80 by 50 to 130 microns, each with a thick yellow-brown membrane. The cyst content often (particularly in the oval cysts) is constricted by the membrane which penetrates deeply. From the side the cyst appears to be divided. Rods in cysts 0.5 by 4 to 8 microns.

Source and habitat: From sterilized rabbit dung on soil (Poland).

Illustrations: Krzemieniewski (*loc. cit.*) Pl. V, Fig. 50, 51.

8. **Polyangium fuscum** (Schroeter) Thaxter. (*Cystobacter fuscus* Schroeter, in Cohn, Kryptogamenflora v. Schlesien, *3*, 1, 1886, 170; Thaxter, Bot. Gaz., *37*, 1904, 414.)

Etymology: Latin *fuscus*, fuscus, brown.

Swarm stage (pseudoplasmodium): Rods slender, elongate, 0.6 by 5 to 12 microns. Grows readily on agar, also on dung agar. Baur states rods are 15 to 20 microns in length and move about 2 to 3 microns per minute in hanging drop, on agar 5 to 10 microns per minute.

Fruiting bodies: Cysts flesh-colored when young, chestnut brown when ripe, spherical, about 60 microns (Thaxter, 50 to 150 by 50 to 70 microns) in diameter, with definite membrane, lying in considerable numbers in large sori, usually 30 to 40 sometimes up to 100. The slime envelope is much more delicate and evanescent than in *P. vitellinum*. Occasionally a form is found with cysts measuring 100 microns: under these often lie kidney shaped cysts even 150 microns in length; apparently, a variety. Rods in cysts about 0.8 to 1.5 by 3 to 3.5 microns. Cysts (Baur) on dung decoction break in 10–12 hours, and rods pour out, apparently passively at first.

P. fuscum var. *velatum* Krzemieniewski differs from the type in that the membrane is thin, separated from cysts, folded.

Source and habitat: Thaxter (Bot. Gaz., *23*, 1897), on rabbit dung from southern California. Kofler (Sitzber. d. Kais. Akad. Wiss. Wien. Math.-Nat. Klasse., 122 Abt., 1913, 845) on rabbit dung, Vienna. Jahn (Die Polyangiden, Geb. Borntraeg., 1924), common on dung,

also occurs on decaying lichens and on poplar bark kept moist. Quite common in Polish soils according to Krzemieniewski (1927, *loc. cit.*).

Illustrations: Thaxter (1897, *loc. cit.*), Pl. 31, Figs. 37–39. Baur, Arch. Protistenkunde, *5*, 1905, Pl. 4, Figs. 14, 15, and 17. Quehl, Cent. f. Bakt., II Abt., *16*, 1906, Pl. 1, Figs. 8 and 16. Jahn, Beiträge zur botanischen Protistologie. I. Die Polyangiden, Geb. Borntraeger. Leipzig, 1924, Pl. 2, Fig. 12. Also Fig. A, p. 9. Krzemieniewski, Acta Soc. Bot. Poloniae, *4*, 1926, 34, Pl. IV, Figs. 42–43, also var. *velatum* Plate IV, Figs. 44–46.

9. **Polyangium aureum** Krzemieniewski. (Acta Soc. Bot. Pol., 7, 1930, 255.)

Etymology: Latin, *aureus*, golden.

Separated from *Polyangium morula* on basis of pigmentation.

Fruiting body: Cysts reddish-brown, variable in number, embedded in yellow slime to form a sorus with a common slime envelope. Cysts nearly spherical or slightly elongate, averaging 32 by 37 microns. Cyst wall orange-yellow, about 3.0 microns thick. Older cysts contain shortened rods, a granular mass, and a colorless or yellowish oleaginous liquid.

Spores: Rod-shaped.

Vegetative cells: Straight rods, of uniform diameter, with rounded ends, 0.7 to 0.9 by 2.8 to 5.3 microns.

Habitat: Soil.

Illustrations: Krzemieniewski (*loc. cit.*) Plate XVII, Figs. 14–17.

10. **Polyangium stellatum** Kofler. (Sitzber. d. kais. Akad. Wiss. Wien, Math.-Nat. Klasse, 122 Abt., 1913, 19.)

Etymology: Latin *stellatus*, stellate.

Swarm stage (pseudoplasmodium): Not described.

Fruiting bodies: Cysts elongate, 80 to 120 microns broad, 160 to 200 microns long, flesh-colored when young, brownish-red when old, star-shaped with 2 to 9 rays fixed by the narrowed base upon a kind of hypothallus.

Source and habitat: Found by Kofler (1913, *loc. cit.*) on hare dung at Vienna.

Illustrations: Kofler (1913, *loc. cit.*) Pl.?, Fig. 6.

11. **Polyangium ferrugineum** Krzemieniewski. (Acta Soc. Bot. Poloniae, *5*, 1927, 97.)

Etymology: Latin *ferrugineus*, dark red, like iron rust.

Swarm stage (pseudoplasmodium): Not described.

Fruiting bodies: Irregular, branched and occasionally constricted coils. Branches of same diameter as the main tube. Cyst wall is brown-red. In the interior no differentiation is visible. Rods in cysts are relatively short and thick, 0.8 to 1.1 microns by 2 to 2.5 microns, not definitely arranged. Close to *Archangium gephyra*, but with cyst walls.

Source and habitat: Krzemieniewski (*loc. cit.*) from soil in Poland and on rabbit dung.

Illustrations: Krzemieniewski (*loc. cit.*) Pl. V, Fig. 21.

12. **Polyangium indivisum** Krzemieniewski. (Acta Soc. Bot. Poloniae, *5*, 1927, 97.)

Etymology: Latin *indivisus*, undivided.

Swarm stage (pseudoplasmodium): Not described.

Fruiting bodies: Similar to *Polyangium ferrugineum*, but much smaller and bright orange-yellow. Enclosed in a similarly colored slime membrane. Interior of coils undifferentiated. Cyst rods 0.8 to 1.0 by 3 to 6 microns, straight, and rounded on ends. Arranged perpendicularly to the wall, giving a netted appearance resembling *Melittangium*.

Source and habitat: From soils in Poland, Krzemieniewski (1927, *loc. cit.*).

13. **Polyangium spumosum** Krzemieniewski. (Acta Soc. Bot. Pol., *7*, 1930, 254.)

Etymology: Latin *spumosus*, foaming, full of foam.

Fruiting body: Colorless sori embedded in hyaline slime forming a common envelope around the cysts. Surface white, foamy in appearance; cysts in irregularly rounded accumulations, 100 to 150 microns in diameter. Cysts usually spherical, sometimes elongate; 18 to 38 by 20 to 50 microns; average 28 by 34 microns. Cyst membrane colorless. Cysts contain bundles of shortened cells, a granular colorless mass, and a clear oleaginous fluid.

Spores: Shortened rods.

Vegetative cells: Straight rods, uniformly thick, with rounded ends; 0.6 to 0.8 by 3.9 to 6.8 microns.

Habitat: Soil.

Illustrations: Krzemieniewski (*loc. cit.*) Plates XVI–XVII, Figs. 10–13.

14. **Polyangium fumosum** Krzemieniewski. (Acta Soc. Bol. Pol., 7, 1930, 253.)

Etymology: Latin *fumosus*, smoky.

Fruiting body: A flat, crust-like layer of 2 to 20 (or more) cysts arranged to form a sorus. Sori rounded, up to 90 microns in diameter, or irregularly shaped; often elongate up to 400 microns long. Smoky-gray color due to surrounding slime walls. Outer profile of sheath (or cortex) irregular. Cyst wall 2.4 to 3.5 microns thick; cysts often nearly spherical, 13 to 48 microns in diameter, though frequently elongate. Average 36 by 44 microns. Colorless, single, inclosed in a transparent membrane.

Spores: No data.

Vegetative cells: Long, straight, cylindrical with rounded ends; 0.7 to 0.9 by 2.7 to 5.7 microns. Encysted cells similar.

Habitat: Soil.

Illustrations: Krzemieniewski (*loc. cit.*) Plate XVI, Figs. 6–9.

15. **Polyangium parasiticum** Geitler. (Arch. f. Protistenkunde, *50*, 1924, 67.)

Etymology: Latin *parasiticus*, parasitic.

Swarm stage (pseudoplasmodium): In water, on surface of the alga *Cladophora*. Pseudoplasmodia small. Rods long, cylindric, rounded at end and 0.7 by 4 to 7 microns. At first saprophytic, later entering and destroying the *Cladophora* cell.

Fruiting bodies: Sometimes single, usually 2 to 8 microscopically small, united in irregular masses, spherical or somewhat elongated. From 15 to 50 microns, usually 25 to 40 microns, with hyaline slime. When mature, red-brown in color, with firm wall.

Source and habitat: Found on *Cladophora (fracta?)* in pool at Vienna (Geitler, 1924).

Illustrations: Geitler (1924, *loc. cit.*) Figs. 1–10.

Genus II. Synangium *Jahn.*

(Jahn, Beiträge zur botan. Protistologie. I. Die Polyangiden, Geb. Borntraeger, Leipzig, 1924, 79; *Apelmocoena* Enderlein, Bakterien-Cyclogenie, Berlin, 1924, 243.)

Etymology: Greek *syn*, together and *angion*, vessel, referring to the clustering of the cysts.

Diagnosis: Cysts provided with an apical point, united more or less completely to rosette-shaped, hemispherical or spherical fruiting bodies.

The type species is *Synangium sessile* (Thaxter) Jahn.

Key to the species of genus Synangium.

I. Cysts irregular, pointed, united as a rosette on a slimy base, without a stalk.
   1. *Synangium sessile.*

II. The fused cysts on a simple or branched stalk.
   A. Cyst group spherical, with the points of the cysts covered as with hair, reddish.
      2. *Synangium lanuginosum.*

B. Cyst group an oblate spheroid, yellow. Points of cysts less numerous.
3. *Synangium thaxteri.*

1. **Synangium sessile** (Thaxter) Jahn. (*Chondromyces sessilis* Thaxter, Bot. Gaz., *37*, 1904, 411; Jahn, Beiträge zur botanischen Protistologie. I. Die Polyangiden, Geb. Borntraeger, Leipzig, 1924, 79.)

Etymology: Latin *sessilis*, sessile, not stalked.

Swarm stage (pseudoplasmodium): Not described.

Fruiting body: Cysts form on the base a clump or rosette without trace of stalk. Diameter of rosettes 100 to 250 microns. Individually the cysts are quite variable in form, irregularly spindle-shaped, usually short-pointed, wrinkled surface toward the tip. At the base they fuse or unite to irregular masses. Cysts 18 to 55 by 25 to 75 microns, average 40 by 50 microns.

Source and habitat: Thaxter (*loc. cit.*) found this on decaying wood in Florida.

Illustration: Thaxter (*loc. cit.*) Pl. 27, Figs. 14–15.

2. **Synangium lanuginosum** (Kofler) Jahn. (*Chondromyces lanuginosus* Kofler, Sitzber. d. Kais. Akad. Wiss. Wien. Math.-Nat. Klasse, 122 Abt., 1913, 861; Jahn, Beiträge zur botanischen Protistologie. I. Polyangiden, Geb. Borntraeger, Leipzig, 1924, 79.)

Etymology: Latin *lanuginosus*, woolly.

Swarm stage (pseudoplasmodium): Not described.

Fruiting body: Cyst cluster, consisting of united cysts, spherical or oval, 80 to 200 microns in diameter, when dry, dark flesh-colored, covered with hairs 15 to 50 microns long, originating from the individual cysts and giving the cyst cluster the appearance of a hairy ball. Skin of the cysts not definite. Rods within the cysts 3 to 6 microns. The cyst clusters are terminal on more or less forked stalks, about 1 mm high.

Source and habitat: Kofler (*loc. cit.*) found this on rabbit dung at Vienna.

Illustrations: Kofler (*loc. cit.*) Pl. 1, Figs. 1–3.

3. **Synangium thaxteri** (Faull) Jahn. (*Chondromyces thaxteri* Faull, Bot. Gaz., *62*, 1916, 226; Jahn, Beiträge zur botanischen Protistologie, I. Die Polyangiden. Geb. Borntraeger, Leipzig, 1924, 79.) Regarded as a synonym of *Synangium lanuginosum* by Krzemieniewski, Acta Soc. Bot. Poloniae, *4*, 1926, 39.

Etymology: Named for Dr. Roland Thaxter, American botanist.

Swarm stage (pseudoplasmodium): Cultured for 2 years on dung, best in mixed cultures. Rods 0.5 by 3 to 6 microns.

Fruiting body: Fruit cluster flattened, spherical, yellow to flesh color or reddish-orange, with a stalk which varys in length, about 140 microns in diameter. The bristles corresponding to the single cysts are 15 to 30 microns long, at the base 10 to 12 microns wide. Sometimes cyst single, usually 3 to 4, occasionally 20 to 30. Rods 0.5 by 3 to 6 microns. Stalk maximum length 0.75 mm, usually 350 microns, single or branched. Broad based, narrowing to apex and yellow in color. In germination rods move from basal scar of membrane, leaving the empty sack behind.

Source and habitat: On deer dung in Ontario, Canada (Faull).

Illustrations: Faull (*loc. cit.*) Pl. 5 and 6. Jahn (*loc. cit.*) Fig. X, p. 80.

Genus III. **Melittangium** *Jahn.*

(Jahn, Beiträge zur botan. Protistologie. I. Die Polyangiden, Geb. Borntraeger, Leipzig, 1924, 78.)

Etymology: Greek *melitta*, bee and *angion*, vessel, because of the honey-comb pattern of the membrane.

Diagnosis: Cysts brownish orange-red, on short white stalk, like a mushroom. Has appearance of a white-stalked *Boletus*. The rods inside stand at right angles to the membrane. Upon germination the covering membrane is left colorless and with an appearance of honey-comb.

The type species is *Melittangium boletus* Jahn.

1. **Melittangium boletus Jahn.** (Beiträge zur botanischen Protistologie. I. Die Polyangiden, Geb. Borntraeger, Leipzig, 1924, 78.)

Etymology: Latin *boletus*, a kind of mushroom.

Swarm stage (pseudoplasmodium): No description.

Fruiting bodies: Cyst stalked, mushroom-like, white when immature, then yellowish-flesh colored, finally yellowish-brown to nut brown, when dried more reddish-brown. Larger diameter of cyst about 100 microns, height 40 to 50 microns, length of white stalk about 40 microns, length of rods in the cyst 3 to 4 microns by 0.5 microns. Sometimes the cyst is smaller and spherical (50 to 60 microns diameter), sometimes there is fusion of neighboring cysts, occasionally the stalk is abortive.

Source and habitat: Jahn (*loc. cit.*) found this not uncommon on rabbit and deer dung in the vicinity of Berlin, also on deer dung from Denmark. Krzemieniewski (1927, *loc. cit.*) reported it as common in Polish soils.

Illustrations: Jahn (*loc. cit.*), Pl. 2, Fig. 17 and 18. Also Fig B, p. 11, C-F, p. 23, O-Q, p. 43, T-U, p. 55. Krzemieniewski, Acta Soc. Bot. Poloniae, *4*, 1926, 1, Pl. V, Fig. 55-56.

Genus IV. Podangium *Jahn.*

(*Cystobacter* Schroeter, in Cohn, Kryptogamenflora v. Schlesien, *3*, 1, 1886, 170; Jahn, Beiträge zur botan. Protistologie. I. Die Polyangiden. Geb. Borntraeger, Leipzig, 1924, 80; *Monocystia* Enderlein, Bakterien-Cyclogenie, Berlin, 1924, 243.)

Etymology: Greek *pus, podis*, foot and *angion*, vessel.

Diagnosis: Cysts chestnut-brown or red-brown, single on a more or less definite white stalk.

The type species is *Podangium erectum* (Schroeter) Jahn.

Key to the species of genus Podangium.

I. Stalk scarcely definite, cysts short, appressed, if elongate then passing over from the white stem into the club-shaped cyst. Ripe cysts chestnut-brown.
   1. *Podangium erectum.*

II. Stalk well differentiated.
   A. Cysts spherical, often irregular, confluent, the white stalk short.
      2. *Podangium lichenicolum.*
   B. Cysts lengthened ellipsoidal, red-brown, definitely differentiated from the white, slender stalks.
      3. *Podangium gracilipes.*

1. **Podangium erectum** (Schroeter) Jahn. (*Cystobacter erectus* Schroeter, in Cohn, Krytogamenflora v. Schlesien, *3*, 1, 1886, 170; *Chondromyces erectus* Thaxter, Bot. Gaz., *23*, 1897, 407; Jahn, Beiträge zur botanischen Protistologie. I. Die Polyangiden, Geb. Borntraeger, Leipzig, 1924, 80.)

Etymology: Latin *erectus*, erect, upright.

Swarm stage (pseudoplasmodium): Kofler states rods are 2 to 5 microns in length.

Fruiting bodies: Cysts usually short, almost spherical, compact, rounded above, orange-red changing to chestnut-brown, single on a white to yellow hypothallus constituted from the slime remaining behind. A definite "foot" of whitish slime is seldom observed. Fifty to hundreds together. Usually about 80 microns high and 40 to 50 microns broad above, smaller below, often spherical cysts 60 microns in diameter. Rods in cysts 0.6 by 4 microns.

Jahn believes the European form to be distinct from that described by Thaxter. Thaxter's form produces cystophores 60 to 300 microns long which wither at maturity so that cysts appear sessile.

Source and habitat: Thaxter (*loc. cit.*), horse dung in laboratory cultures, Massachusetts. Kofler (Sitzber. d. Kais. Akad. Wiss. Wien. Math.-Nat. Klasse, 122 Abt., 1913), mouse dung. Jahn (1924) common on manure of different kinds, also on bark covered with lichens. Krzemieniewski (Acta Soc. Bot. Pol., *5*, 1927, 102) reported this species from Polish soil, but rare.

Illustrations: Thaxter (*loc. cit.*) Pl. 31, Figs. 16–19. Quehl, Cent. f. Bakt., II Abt., *16*, 1906, Pl. 1, Figs. 4. Jahn (*loc. cit.*) Pl. I, Figs. 7, 8, and 9. Krzemieniewski, Acta Soc. Bot. Poloniae, *4*, 1926, 1, Pl. V, Figs. 52–53.

2. **Podangium lichenicolum** (Thaxter) Jahn. (*Chondromyces lichenicolus* Thaxter, Bot. Gaz., *17*, 1892, 402; Jahn, Beiträge zur botanischen Protistologie. I. Die Polyangiden, Geb. Borntraeger, Leipzig, 1924, 81.)

Etymology: Greek *lichen*, tree moss, lichen. Latin *-colus*, dwelling.

Swarm stage: Reddish, rods cylindrical, tapering slightly, 0.6 by 5 to 7 microns. Germinate readily after drying for 18 months when sown on moist lichens.

Fruiting bodies: Cysts single, rounded or irregularly lobed, often confluent. Cystophore short, squarish, often lacking or misshapen. Cysts 28 to 35 microns, stem 7 to 8 by 10 microns.

Source and habitat: Thaxter (1892), parasitic upon living lichens, which it destroys, New Haven, Conn. Thaxter (1904, *loc. cit.*), lichens, Indiana, on algae, seen on wet boards, in mill race, Massachusetts.

Illustrations: Thaxter (1892, *loc. cit.*) Pl. 23, Figs. 20 to 23. Quehl, Cent. f. Bakt., II Abt., *16*, 1906, 9, Pl. 1, Fig. 6.

3. **Podangium gracilipes** (Thaxter) Jahn. (*Chondromyces gracilipes* Thaxter, Bot. Gaz., *23*, 1897, 406; Jahn, Beiträge zur botanischen Protistologie. I. Die Polyangiden, Geb. Borntraeger, Leipzig, 1924, 82.)

Etymology: Latin *gracilipes*, slender footed.

Swarm stage: Rods 5 to 7 microns.

Fruiting bodies: Cysts bright orange-red, or red, 25 by 35 microns, elongate, rounded, on a white pointed stalk, rigid and persistent on substratum, rods also in stalk. Shortened rods in cyst 3 to 5 microns. Cysts sometimes pear-shaped, caducous.

Source and habitat: Thaxter (*loc. cit.*), from rabbit dung, Massachusets. Kofler (1913, *loc. cit.*), dung, Vienna. Jahn (*loc. cit.*) relatively common. Twice on rabbit dung near Berlin, once on goat dung in Norway. Krzemieniewski (1927 *loc. cit.*) reported this species from Polish soil, but rare.

Illustrations: Thaxter (*loc. cit.*) Pl. 31, Figs. 20–24. Quehl, Cent. f. Bakt., II Abt., *16*, 1906, Pl. 1, Fig. 12. Jahn (*loc. cit.*) Pl. II, Figs. 19, 20. Krzemieniewski (1926, *loc. cit.*), Pl. V, Fig. 54.

Genus V. **Chondromyces** *Berkeley and Curtis.*

(See Berkeley, Introduction to Cryptogamic Botany, London, 1857, 313; *Stigmatella* Berkeley and Curtis, *ibid.* 1857, 313 (figure but no description); Berkeley (description), Notes on North American Fungi, Grevillea, *3*, 1874, 97; see Berkeley and Curtis, in Saccardo, Sylloge Fungorum, *4*, 1886, 679, *Polycephalum*? Kalchbrenner and Cooke, Grevillea, *9*, 1880, 22; *Myxobotyrs* Zukal, Ber. d. deutsch. Bot. Gesellsch., *14*, 1896, 346; *Cystodesmia* Enderlein, Bakterien-Cyclogenie, Berlin, 1924, 243.)

Synonymy: A species was figured and named in 1857 by Berkeley as *Chondromyces crocatus* Berkeley and Curtis, but not described. The generic name was finally described in 1874. Probably the date of the name should be the date of its description, although it is possible that an adequate labeled illustration should be interpreted as valid publication.

Etymology: Greek *chondros*, grain and *myces*, (fungus).

Diagnosis: Cysts compactly grouped at the end of a colored stalk (cystophore). Cystophore simple or branched.

The type species is *Chondromyces crocatus* Berkeley and Curtis.

Key to the species of genus **Chondromyces.**

I. Cysts not in chains.
  A. Cysts sessile when ripe.
    1. Cysts not pointed.
      a. Cysts rounded.
        b. Yellow.
          1. *Chondromyces crocatus.*
        bb. Bright orange-red.
          2. *Chondromyces aurantiacus.*
      aa. Cysts cylindrical.
          3. *Chondromyces cylindricus.*
    2. Cysts pointed.
          4. *Chondromyces apiculatus.*
  B. Cysts borne on stalk or stipe when ripe.
    1. Cysts orange-colored and truncate or rounded at distal end.
      a. Cystophore usually simple.
          5. *Chondromyces pediculatus.*
      aa. Cystophore usually branched.
          6. *Chondromyces medius.*
    2. Cysts copper-red when ripe; pear-shaped.
          7. *Chondromyces minor.*
II. Cysts in chains at end of a compact stalk.
          8. *Chondromyces catenulatus.*

1. **Chondromyces crocatus** Berkeley and Curtis. (Berkeley, Introduction to Cryptogamic Botany, London, 1857, 313; Berkeley, Notes on North American Fungi, Grevillea, *3*, 1874, 64; *Myxobotyrs variabilis* Zukal, Ber. d. deutsch. bot. Ges., *15*, 1896, 340, according to Krzemieniewski, Acta Soc. Bot. Poloniae, *4*, 1926, 38.)

Etymology: Latin *crocatus*, saffron yellow.

Swarm stage (pseudoplasmodium): Pale orange-red. Rods cylindrical or tapering slightly, straight or slightly curved, 0.6 to 0.7 by 2.5 to 6 microns. Cultivated on nutrient agar and sterilized horse dung. Cysts placed in moist chamber germinate in one or two days.

The contents are first contracted within the cyst walls, showing the individual rods. The cyst wall is then absorbed or disappears at the base, and the rods escape in a regular stream until only the empty cyst is left.

Fruiting bodies: Cysts nearly conical, rounded at tip, average 12 by 28 microns (6 to 20 by 15 to 45 microns), straw yellow, in spherical heads of variable numbers (70 to 90 microns) at tips of branches. Cystophore orange-colored, slender, striated, often twisted or irregularly bent, simple or branched as many as 5 times. About 600 microns high, rarely 1 mm.

Source and habitat: Thaxter (1892, *loc. cit.*), melon rind from South Carolina and old straw from Ceylon and Cambridge, Mass. Zukal (*loc. cit.*), Vienna. Quehl, dung from Java and on deer dung, near Berlin. Thaxter (1904, *loc. cit.*), New Haven, Conn., Tabor, Iowa, Florida, Laubach, Java.

Illustrations: Berkeley, Introduction to Cryptogamic Botany, London, 1857, 313. Thaxter, Bot. Gaz., *17*, 1892, 389, Pl. 22 and 23, Figs. 1–11. Quehl, Cent. f. Bakt., II Abt., *16*, 1906, 9, Pl. 1, Fig. 10. Jahn, Kryptogamenflora der Mark Brandenburg, V, Pilze I, Lief 2, 1911, 199, Fig. 6. Jahn, Beiträge zur botanischen Protistologie, I. Die Polyangiden, Geb. Borntraeger, Leipzig, 1924, Pl. 2, Figs. 14, 15, and 16.

2. **Chondromyces aurantiacus** (Berkeley and Curtis) Thaxter. (*Stigmatella aurantiaca* Berkeley and Curtis (no description), Introduction to Cryptogamic Botany, London, 1857, 313; Berkeley (description), Notes on North American Fungi, Grevillea, *3*, 1874, 97; *Stilbum rhytidosporum* Berkeley and Browne, 1873, 96, see Saccardo, Sylloge Fungorum, *4*, 1886, 571; *Polycephalum aurantiacum* Kalchbrenner and Cooke, Australian Fungi, Grevillea, *9*, 1880, 23; *Myxobotrys variabilis* Zukal, Ber. deutsch. Bot. Ges., *14*, 1896, 340; *Chondromyces aurantiacus* Jahn, Kryptogamenflora der Mark Brandenburg, V, Pilze I, 1911, 206.)

Etymology: Modern Latin *aurantiacus*, orange-colored.

Swarm stage (pseudoplasmodium): Flesh-colored, distinctly reddish. Rods large, tapering somewhat, normally straight, rounded at either extremity, 0.6 to 1 by 7 to 15 microns, average 0.5 by 7 microns (?). Easily cultivated on nutrient agar, but on this rarely produces well formed cystophores, though cultivable on its ordinary substrate without difficulty.

Fruiting bodies: Cysts oval, elliptical or spherical, average 30 by 50 microns, at first stalked then sessile, united in small numbers at one end of cystophores, bright orange-red, chestnut-brown when kept moist for a considerable period or flesh-colored. Cystophore colorless, often yellowish at the tip, usually simple, rarely forked, 200 to 400 microns high.

The Krzemieniewskis (Acta Soc. Bot. Poloniae, *5*, 1927, 96) have described a *Chondromyces aurantiacus* var. *frutescens* in which the fruiting body consists of a greenish, later yellowish mass of rods which develops into a thick cystophore with numerous terminal cysts. The cysts are oval or spherical, sometimes with cross-striations, first orange-colored, later brown, about 40 to 120 by 30 to 90 microns. The cyst rods are 0.9 to 1.0 by 2.3 to 3.4 microns.

Source and habitat: Berkeley (1857, *loc. cit.*), on lichen. Berkeley and Brown (1873, *loc. cit.*), on rotten wood from Ceylon. Thaxter (1892, *loc. cit.*) in North America not uncommon on old wood and fungi. Zukal (*loc. cit.*), Vienna. Thaxter, Bot. Gaz., *23*, 1897 395, on antelope dung from Africa. Thaxter, Bot. Gaz., *37*, 1904, 405, Florida, Philippines. Quehl, Cent. f. Bakt., II Abt., *16*, 1906, 9, dung from Java. Krzemieniewski, Acta Soc. Bot. Poloniae, *4*, 1926, 1, rare in Polish soils.

Illustrations: Berkeley and Brown

(1873, *loc. cit.*) Pl. 4, Fig. 16. Kalchbrenner and Cooke (*loc. cit.*). Thaxter (1892, *loc. cit.*) Pl. 23 and 24, Figs. 12–19 and 25–28. Zukal (*loc. cit.*) Pl. 20. Quehl (*loc. cit.*) Pl. 1, Fig. 10. Jahn, Beiträge zur botanischen Protistologie, I. Die Polyangiden, Geb. Borntraeger, Leipzig, 1924, Fig. V, p. 57, Fig. W, p. 59. Krzemieniewski (1926, *loc. cit.*), Pl. V, Figs. 57–60; (1927) var. *frutescens* Pl. VI, Figs. 27–35.

3. **Chondromyces cylindricus** Krzemieniewski. (Acta Soc. Bot. Pol., *7*, 1930, 260.)

Etymology: Greek *kylindrikos*, cylindrical.

This organism was at first thought to be a variety of *Chondromyces aurantiacus*. It is separated from it on the basis of size, shape and pigmentation of the cysts.

Fruiting body: Cystophore composed of bundles of cells, develops from a thick, greenish-yellow mass of rods; unbranched or with short branches, colorless to pale orange-yellow; up to 200 microns high. Numerous cysts develop from cystophore and branches; at first borne on slender stipe 20 microns long, later becoming sessile on cystophore. Young cysts orange-yellow, later becoming deeper orange, and finally bright orange-brown when ripe. Shape variable: oval, irregularly rounded; predominantly cylindrical with rounded ends, 16 to 49 by 30 to 90 microns; average 29 by 56 microns.

Spores: Shortened rods 0.8 to 1.1 by 1.8 to 3.3 microns.

Vegetative cells: Long rods, tapered at ends, 0.5 to 0.6 by 6.7 to 11.0 microns.

Habitat: Soils.

Illustrations: Krzemieniewski (*loc. cit.*) Plate XVII, Fig. 18.

4. **Chondromyces apiculatus** Thaxter. (Bot. Gaz., *23*, 1897, 405.)

Etymology: Modern Latin from Latin *apex*, a point: with a small point.

Swarm stage (pseudoplasmodium): Rods 1 by 3 to 20 microns. Does not grow as well on nutrient agar as *Chondromyces crocatus* and produces cysts and cystophores rarely. Cultivated on dung. Kofler states rods are 3 to 5 microns in length.

Fruiting bodies: Cysts of variable form, cylindrical to broadly turnip-shaped, usually with basal and apical appendages, the latter longer and pointed, bright orange, 28 by 35 microns. Cysts united in a single spherical terminal head, about 200 microns in diameter. Cystophore rigid, stiff, seldom branched, to 1 mm high, colorless, longitudinally striate. Cysts germinate at both base and apex.

Source and habitat: Thaxter (1897, *loc. cit.*), on antelope dung from Africa. Thaxter (1904, *loc. cit.*), deer dung, Philippines, Florida. Baur (1906, *loc. cit.*), on rabbit dung near Berlin. Kofler (1913, *loc. cit.*), on rabbit dung near Vienna.

Illustrations: Thaxter (1897, *loc. cit.*) Pl. 30, Figs. 1 to 15. Quehl (1906, *loc. cit.*), Pl. 1, Figs. 13 to 14. Jahn (1911, *loc. cit.*) p. 199, Fig. 5.

5. **Chondromyces pediculatus** Thaxter. (Bot. Gaz., *37*, 1904, 410.)

Etymology: From Latin *pediculus*, a small foot; small footed (stalked).

Swarm stage (pseudoplasmodium): Rods 0.6 to 0.7 by 2 to 4 microns.

Fruiting bodies: Cysts rounded to bell-shaped, truncate at distal end, orange-yellow, when dry orange-red, 35 to 50 microns. Sessile on stalks 40 to 60 microns in length, which are arranged as an umbel on the tip of the cystophore. Cystophore 300 to 700 microns in length, solitary, simple, usually rather slender and somewhat wrinkled.

Source and habitat: Thaxter (*loc. cit.*), on goose dung in South Carolina.

Illustrations: Thaxter (*loc. cit.*) Pl. 26, Figs. 7 to 13.

6. **Chondromyces medius** Krzemieniewski. (Acta Soc. Bot. Pol., *7*, 1930, 263.)

Etymology: Latin *medius*, medial, moderate.

Fruiting body: Glistening, orange-colored cysts attached to cystophore in clusters by means of filamentous stipes about 40 microns long. Deciduous. Mass of rod-shaped cells from which cystophore develops colorless to pink. Cystophore composed of bundles of cells, often branched; appear similar to those of *Chondromyces aurantiacus* var. *frutescens*. Cysts variable in shape; predominant are those rounded or flattened at the apex and tapered toward the base, 24 to 78 by 26 to 93 microns. Average 51 by 55 microns.

Spores: No data.

Habitat: Soil.

Illustrations: Krzemieniewski (*loc. cit.*) Plate XVII, Figs. 20–22.

7. **Chondromyces minor** Krzemieniewski. (Acta Soc. Bot. Pol., 7, 1930, 265.)

Etymology: Latin *minor*, less, little, small.

Fruiting body: Cell masses from which cystophore develops, reddish-violet in color. Cystophore white, simple or branched, up to 120 microns high, 17 to 89 microns thick. Cysts borne in clumps of 2 to 20 at apex of cystophore and branches on delicate colorless stipes. Cysts rose-red becoming copper-red when dry; pear-shaped, tapering toward base and broad at the apex; 20 to 47 by 20 to 65 microns; average 28 by 38 microns. Deciduous. Stipes 3 to 6 by 10 to 25 microns.

Spores: 0.6 to 0.8 by 2.9 to 4.3 microns.

Vegetative cells: 0.6 by 3.8 to 7.2 microns.

Habitat: Soil.

Illustrations: Krzemieniewski (*loc. cit.*) Plate XVII, Figs. 23–24.

8. **Chondromyces catenulatus** Thaxter. (Bot. Gaz., *37*, 1904, 410.)

Etymology: Modern Latin from *catena*, a chain, = occurring in chains.

Swarm stage (pseudoplasmodium): Cultivated only on original substrate. Rods 1 to 1.3 by 4 to 6 microns.

Fruiting bodies: Cysts light yellow-orange, 20 to 50 by 18 microns in rosary-like chains, which may be branched once or twice, sessile on a short compact stalk, cysts separated by shriveled isthmuses. Chains to 300 microns. Cystophore simple 180 to 360 microns, cleft above, and passing over into the chains, rather broad at base and spreading somewhat on substratum. The divisions of the cystophore are pointed, short and slightly swollen.

Source and habitat: Thaxter (*loc. cit.*), on decaying poplar wood, New Hampshire.

Illustrations: Thaxter (*loc. cit.*) Pl. 26, Figs. 1 to 5.

FAMILY V. MYXOCOCCACEAE JAHN.

(Beiträge zur botan. Protistologie. I. Die Polyangiden, Geb. Borntraeger, Leipzig, 1924, 84.)

Diagnosis: The rods become shortened when fruiting occurs (resting cells are formed), and develop into spherical or ellipsoidal spores or microcysts. Upon germination the vegetative cell develops from the spore by a process analogous to budding, pinching off at the point of emergence, leaving the spore wall entirely empty. In three of the genera, definite fruiting bodies are produced. In *Sporocytophaga*, the spores (microcysts) are produced from the vegetative cells without development of fruiting bodies.

Key to the genera of family **Myxococcaceae.**

I. Definite fruiting bodies formed.
  A. Fruiting body not containing or made up of cysts.
    1. Fruiting bodies deliquescent.
      Genus I. *Myxococcus*, p. 1040.
    2. Fruiting bodies firm, not deliquescent.
      Genus II. *Chondrococcus*, p. 1044.
  B. Fruiting body made up of cysts.
    Genus III. *Angiococcus*, p. 1047.
II. No definite fruiting bodies formed.
  Genus IV. *Sporocytophaga*, p. 1048.

Genus I. **Myxococcus** *Thaxter.*

(Bot. Gaz., *17*, 1892, 403.)

Etymology: Greek *myxa*, mucus and *kokkos*, berry; slime sphere.

Diagnosis: Spherical spores in conical or spherical or occasionally ovoid upright fruiting bodies, united by a loose more or less mobile slime.

The type species is *Myxococcus fulvus* (Cohn *emend.* Schroeter) Jahn.

Key to the species of genus **Myxococcus.**

I. Stalk lacking or indicated only by a constriction.
  A. Spores average less than 1.4 microns in diameter.
    1. Fruiting body red or brownish-flesh color.
      1. *Myxococcus fulvus.*
    2. Fruiting body light blood-red.
      2. *Myxococcus cruentus.*
  B. Spores average 2.0 microns in diameter.
    1. Fruiting body yellow to greenish-yellow.
      3. *Myxococcus virescens.*
    2. Fruiting body yellow-orange to orange.
      4. *Myxococcus xanthus.*
II. Well developed stalk supporting spherical spore mass above.
  A. Spores spherical.
    5. *Myxococcus stipitatus.*
  B. Spores oval.
    6. *Myxococcus ovalisporus.*

1. **Myxococcus fulvus** (Cohn *emend.* Schroeter) Jahn. (*Micrococcus fulvus* Cohn?, Beiträge z. Biologie d. Pflanzen, *1*, Heft 3, 1875, 181; Jahn (1924) states that the description of Cohn is too inadequate to determine whether he was dealing with a true species of the genus *Myxococcus*. Cohn described the organism from horse dung, as producing conical, rust-red droplets ½ mm in diameter, the cells bound together by an intercellular slime, cells large, 1.5 microns in diameter; *Micrococcus fulvus* Schroeter, Schizomycetes, in Cohn, Kryptogamenflora v. Schlesien, *3*, 1, 1886, 144. Observed on horse dung and rabbit dung at various localities. Jahn insists that this organism must be the same as *Myxococcus rubescens* Thaxter. *Myxococcus rubescens* Thaxter, Bot. Gaz., *17*, 1892, 403; *Myxococcus ruber* Baur, Arch. f. Protistenkunde, *5*, 1905, 95; *Myxococcus pyriformis* A. L. Smith, Jour. Bot., *39*, 1901, 71; *Myxococcus javanensis* de Kruyff, Cent. f. Bakt, II Abt., *21*, 1908, 386; *Rhodococcus fulvus* Winslow and Winslow, Systematic Relationships of the Coccaceae, 1908, 262; *Myxococcus fulvus* Jahn, Beiträge zur botanischen Protistologie. I. Die Polyangiden, Geb. Borntraeger, Leipzig, 1924, 84.)

Etymology: Latin *fulvus*, reddish-yellow.

Swarm stage (pseudoplasmodium): Thaxter states that the rod masses are reddish, rods slender, irregularly curved, 0.4 by 3 to 7 microns. Bauer followed spore germination in hanging drop. Spores 0.8 to 1.3 microns, without structure, in five hours swollen to 1 to 1.5 microns, and no longer as refractive. The membrane is not burst; the cell becomes egg-shaped, then elongate and cylindric. He regards his *Myxococcus ruber* as distinct from Thaxter's *Myxococcus rubescens* in part because of differences in spore germination. The cells become motile after doubling or trebling in length. It is a creeping motion in contact with the substrate; the cells do not "swim." Rate of motion 5 to 10 microns per minute. Rods eventually are 0.5 to 0.7 microns by 4 to 10 microns. Cell division by transverse fission. Spore formation is through shortening and rounding of the cells, the converse of germination. In hanging drop the cells tend to congregate after three days and to transform into spores. Rods sporulate in 3 to 4 hours. The rods continue to congregate, and the spore mass increases, held together by viscous matrix. Vegetative cells are light flesh color.

Gelatin is quickly liquefied, completely in 1 to 2 days, but no fruiting bodies are formed.

Kofler secured good growth on Hasting's milk agar, and determined digestion of casein.

Baur could not secure good growth on any agar medium of known composition. With peptone, sugars, etc., some growth but not normal when peptone present. He carried one strain 3½ months on peptone sugar agar. Good growth on dung agar. Addition of peptone to dung agar not significant in effect, the addition of glucose altered the form of the fruiting bodies.

De Kruyff secured best results with a dung extract agar to which was added ammonium nitrate and potassium phosphate.

Fruiting bodies: Spherical or elongate pear-shape, constricted below, often with definite slimy stalk, flesh red to brownish-red, when dry rust-red to brown, about 300 microns in diameter. Spores 1 to 1.2 microns. Jahn (1924, *loc. cit.*) notes two varieties.

- var. *albus*. (Latin *albus*, white). Constantly white, even when transferred. Fruiting bodies somewhat smaller than the type.
- var. *miniatus*. (Latin *miniatus*, painted with red lead or cinnabar.) Color cinnabar-red, fruiting bodies somewhat larger.

The form described by de Kruyff had spores 1.6 microns in diameter.

Source and habitat: Thaxter (1892, *loc. cit.*), on various decaying substances, lichens, paper, dung, etc. Smith (*loc. cit.*), on rabbit dung from Wales. Baur (*loc. cit.*), on cow and dog dung. De Kruyff (*loc. cit.*), on stable manure in Java. Jahn (1924, *loc. cit.*), very common, on almost all specimens of dung, also on bark, decaying wood, and lichens. Krzemieniewski (1927, *loc. cit.*) very common in Polish soil. Kofler (*loc. cit.*), dung of rabbit, horse, goat, mouse, roe, deer, on stem of clematis and decaying leaves and in bird nest.

Illustrations: Cohn (*loc. cit.*) Pl. 6, Fig. 18. Smith (*loc. cit.*) Fig. 1. Baur (*loc. cit.*) Figs. 1, 2, 3, and Pl. 4, Figs. 1–13, 16. Jahn (1924, *loc. cit.*) Figs. L–M, p. 43, Fig. R, p. 47. Krzemieniewski, Acta Soc. Bot. Poloniae, *4*, 1926, Pl. I, Figs. 7–8. Kofler, Sitzber. d. Kais. Akad. Wiss. Wien. Math.-Nat. Klasse, 122 Abt., 1913, 845, Pl. 2, Figs. 10 and 12.

Cultures: Baur (*loc. cit.*) states that he deposited a pure culture in the Zentralstelle für Pilzkulturen.

2. **Myxococcus cruentus** Thaxter. (Thaxter, Bot. Gaz., *23*, 1897, 395; *Chondrococcus cruentus* Krzemieniewski, Acta Soc. Bot. Poloniae, *5*, 1927, 79.)

Etymology: Latin *cruentus*, blood-red.

Swarm stage (pseudoplasmodium): Rods 0.8 by 3 to 8 microns. Was not cultivated.

Fruiting body: Cysts regularly spherical, 90 to 125 microns, blood-red. Slime forms on the surface a more or less definite membrane, in which the spores lie. Spores oval or irregularly oblong about 0.9 to 1 by 1.2 to 1.4 microns. Cysts are densely aggregated.

Source and habitat: Thaxter (*loc. cit.*), on cow dung, Tennessee. Krzemieniewski (1927, *loc. cit.*) rare in Polish soils.

Illustrations: Thaxter (*loc. cit.*) Pl. 31, Figs. 28–29.

3. **Myxococcus virescens** Thaxter. (Bot. Gaz., *17*, 1892, 404.)

Etymology: Latin *virescens*, becoming green.

Swarm stage (pseudoplasmodium): Rod masses greenish-yellow. Rods slender, irregularly curved, 0.4 by 3 to 7 microns. When cultivated in potato agar tends to lose its green color and becomes yellowish. Badian (1930) reports the presence of a dumb-bell-shaped nuclear structure which splits longitudinally in cell division, and shows autogamy preceding and a reduction division during spore formation.

Fruiting body: Spherical or conical, usually less rounded than other species of the genus, yellowish, occasionally greenish, in culture on artificial media, easily becoming white, 150 to 500 microns. The slime deliquesces in continued moisture. Spores large, about 2 microns.

Source and habitat: Thaxter (*loc. cit.*), on hen's and dog's dung, New England. Jahn (1924, *loc. cit.*), not very abundant on dung of rabbit, horse, stag and black cock. Krzemieniewski (1927, *loc. cit.*), common in soil in Poland. Badian (*loc. cit.*), Poland.

Illustrations: Krzemieniewski, Acta Soc. Bot. Poloniae, *4*, 1926, Pl. I, Fig. 9. Badian, Acta Soc. Bot. Poloniae, *7*, 1930, 55, Pl. 1, 8 figures.

4. **Myxococcus xanthus** Beebe. (Jour. Bact., *42*, 1941, 193.)

Etymology: Greek *xanthos*, orange, golden.

Fruiting body: Spherical to subspherical, usually sessile but occasionally constricted at the base giving the appearance of a short stalk or foot. Mature fruiting body up to 300 to 400 microns in diameter, often slightly flattened on top or one side. Color varies from light yellowish-orange when young to bright orange when mature; color constant, never tending toward greenish-yellow. No outer cyst wall or

limiting membrane discernible, the spores being imbedded in the slime holding the mass together. Usually single, though two or three fruiting bodies may become joined to form an irregular mass; each is attached to the substrate, however, and never bud one from another.

Spores: Spherical, with thick outer wall or membrane. Highly refractile. Stain very easily with any of the ordinary bacterial or nuclear dyes. 2.0 microns in diameter, seldom larger.

Vegetative cells: Large, flexible, single, Gram-negative rods with rounded ends. No flagella, but move on surface of solid or semi-solid substrate with a crawling or creeping motion. Vary in size from 0.5 to 1.0 by 4 to 10 microns; average 0.75 by 5 microns. More or less distinct cell wall often evident.

Vegetative colony: Characteristics vary with the substrate.

On plain 1.5 per cent agar (no nutrients added): Very thin and transparent, often hardly visible except by transmitted light. Little or no pigmentation. Surface covered with fine, more or less regularly spaced ridges causing a dull macroscopic appearance without gloss or sheen. Margin very thin and quite regular.

On rabbit dung decoction agar: Colony thicker, the surface being broken by veins or ridges radiating from the center. Thick central area often smooth and glossy while margin much the same as that on plain agar. Veins or ridges extend outward from center in loose spiral, always in clock-wise direction. Pigmentation, yellow to pale orange, confined to thicker central portion, extends part way along veins to margin.

On nutrient agar: Growth poor. Colony thick, at first heavily veined, the veins later merging to form an irregular glossy surface. Colony remains small, pigmentation usually fairly heavy; margin thick, irregular to lobate.

Physiology: Grows well on mineral salt-agar to which has been added dulcitol, inulin, cellulose, reprecipitated cellulose or starch; hydrolyzes starch; does not destroy cellulose to any appreciable extent. Best growth on suspension of killed bacterial cells in agar; suspended cells in growth area lysed. Development completely inhibited by arabinose, largely by maltose and mannose.

Source: Isolated from dried cow dung, Ames, Iowa.

Habitat: Decomposed bacterial cells in dung.

Illustrations: Beebe (*loc. cit.*) Figs. 1–28.

5. **Myxococcus stipitatus** Thaxter. (Bot. Gaz., *23*, 1897, 395.)

Etymology: From Latin *stipes*, stalk; stalked.

Swarm stage (pseudoplasmodium): Rods 0.5 to 0.7 by 2 to 7 microns or longer. Grows well on nutrient agar, but does not fruit readily.

Fruiting body: Spore mass nearly spherical, 175 microns in diameter, deliquescent, sessile on a well developed compact stalk, white to yellowish and flesh color. Spores 0.8 to 1.2 by 1.0 to 1.15 microns. Stalk 100 to 200 microns long, 30 to 50 microns wide.

Source and habitat: Thaxter (*loc. cit.*), repeatedly on dung in laboratory cultures at Cambridge, Mass., Maine, Tennessee. Krzemieniewski (1927, *loc. cit.*), common in Polish soils.

Illustrations: Thaxter (*loc. cit.*) Pl. 31, Figs. 30 to 33. Krzemieniewski, Acta Soc. Bot. Poloniae, *4*, 1926, Pl. II, Figs. 13–14.

6. **Myxococcus ovalisporus** Krzemieniewski. (Acta Soc. Bot., Pol., *4*, 1926, 15.)

Etymology: Modern Latin *ovalis*, oval, Greek *sporos*, seed. Oval spored.

Swarm stage (pseudoplasmodium): Not described.

Fruiting bodies: Produces almost spherical, characteristically shortened, ovoid

spore masses of light milky yellow color. These are often raised on a poorly developed stalk. This stalk always shows some bacterial cells remaining, and in this and color is differeniated from *M. stipitatus*. From the base of the stalk or directly from the substrate one or more small fruiting bodies develop. Spores are oval, sometimes irregularly spherical, 1.3 to 1.9 by 1.0 to 1.4 microns. In culture retains its differences from *Myxococcus stipitatus*. The latter sporulates best at room temperature, but *Myxococcus ovalisporus* in an incubator (presumably at 37°C).

Source and habitat: Develops on rabbit dung (sterilized) on soil in Poland (Krzemieniewski).

Appendix: Rippel and Flehmig (Arch. f. Mikrobiol., *4*, 1933, 229) describe a new type of aerobic cellulose destroying bacteria under the new genus name of *Itersonia*. This genus includes a single species, *Itersonia ferruginea*. This organism shows similarity to those included in *Myxococcus*.

Genus II. **Chondrococcus** *Jahn.*

(Jahn, Beiträge zur botan. Protistologie. I. Die Polyangiden, Geb. Borntraeger, Leipzig, 1924; *Dactylocoena* Enderlein, Bakterien-Cyclogenie, Berlin, 1924, 243.)

Synonymy: A segregate from *Myxococcus* Thaxter.

Etymology: Greek *chondros*, grain and *kokkos*, ball (coccus).

Diagnosis: Spores embedded in a viscous slime which hardens. Fruiting bodies divided by joints or constrictions, often branched, usually relatively small.

Seven species are included, of which the first described by Thaxter and best described, *Chondrococcus coralloides* (Thaxter) Jahn, may be designated as the type. The first species listed by Jahn is regarded as doubtful and should not be regarded as the type for there is no evidence that Jahn ever saw the species.

Key to the species of genus **Chondrococcus.**

I. Not parasitic on fish.
  A. Erect, simple or somewhat branched fruiting bodies.
    1. Secondary fruiting bodies not produced.
      a. Fruiting bodies constricted or jointed.
        1. *Chondrococcus coralloides.*
      aa. Fruiting body simple, columnar, club- or cushion-shaped.
        b. Fruiting body thick below, lesser above.
          2. *Chondrococcus cirrhosis.*
        bb. Not as in b.
          c. Spores 1.6 to 2.0 microns in diameter.
            d. Fruiting body cushion-shaped.
              3. *Chondrococcus megalosporus.*
            dd. Fruiting body branched.
              4. *Chondrococcus macrosporus.*
          cc. Fruiting body smaller below, above club-shaped. Spores 1.0 to 1.2 microns in diameter.
            1a. *Chondrococcus coralloides* var. *clavatus.*
    2. Secondary fruiting bodies arise as bud-, finger- or coral-like growths from primary fruiting body.
      5. *Chondrococcus blasticus.*
  B. Recumbent, simple swelling or cyst heap constituting the fruiting body.

1. Cysts 60 to 170 microns, without definite envelope, in swollen brain-like arrangement.

6. *Chondrococcus cerebriformis.*

2. Cysts 30 to 35 microns, numerous, and embedded in a thick slime envelope.

1b. *Chondrococcus coralloides* var. *polycystus.*

II. Parasitic on fish.

7. *Chondrococcus columnaris.*

1. **Chondrococcus coralloides** (Thaxter) Jahn. (*Myxococcus coralloides* Thaxter, Bot. Gaz., *17*, 1892, 404; *Myxococcus digitatus* Quehl, Cent. f. Bakt., II Abt., *16*, 1906, 18 (*pro parte*); *Myxococcus clavatus* Quehl, *ibid.*; *Myxococcus polycystus* Kofler, Sitzberg. d. kais. Wiss., Wien. Mat.-Nat. Klasse, 122 Abt., 1913, 865 (*pro parte*); *Myxococcus exiguus* Kofler, *ibid.*, 867 (*pro parte*); *Chondrococcus polycystus* Krzemieniewski, Act. Soc. Bot. Poloniae, *4*, 1926, 46.)

Etymology: Greek *korallion*, coral, *eidos*, like.

Swarm stage (pseudoplasmodium): Rod masses pale pinkish, thin, rods slender, curved 4 to 7 by 0.4 microns. Readily cultivated on lichens and on potato agar.

Fruiting bodies: Very variable in shape, usually with rounded coral-like processes, recumbent or upright, sometimes with finger-like outgrowths or rounded constrictions, usually small, about 50 microns in diameter, protuberances 20 to 30 microns wide, light rose to flesh color. Spores 1 to 1.2 microns. Jahn concludes that the species segregated by Quehl and by Kofler are of varietal rank only. Krzemieniewski (1926) regards *Chondrococcus polycystus* (Kofler) Krzemieniewski as a distinct species.

Source and habitat: Thaxter (1892), uncommon in America, on lichens. Very common in Europe. Jahn (1924), relatively common. On dung of rabbit, hare, horses, deer, old bark and old lichens. Goat dung from Lapland and Italy. Kofler (1913), dung of field mice, horses, hares, goats, roe and deer. Krzemieniewski (1927), common in Polish soil.

Illustrations: Thaxter (1892, *loc. cit.*) Pl. 24, Figs. 29-33. Quehl (1906, *loc. cit.*) Pl. 1, Figs. 1 and 9. Kofler (1913, *loc. cit.*) Pl. 1, Fig. 4, Pl. 2, Fig. 9. Krzemieniewski (1926, *loc. cit.*) Pl. II, Figs. 15–18. Jahn (1924, *loc. cit.*) Fig. Y, p. 87.

1a. *Chondrococcus corralloides* var. *clavatus* varies from *Chondrococcus coralloides* in having fruiting bodies simple or branched rather than constricted or jointed.

1b. *Chondrococcus corralloides* var. *polycystus* varies from *Chondrococcus coralloides*, in having its fruiting bodies simple swellings or "cyst heaps" rather than branched, and in being recumbent rather than erect.

2. **Chondrococcus cirrhosus** (Thaxter) Jahn. (*Myxococcus cirrhosus* Thaxter, Bot. Gaz., *23*, 1897, 409; Jahn, Beiträge zur botanischen Protistologie. I. Die Polyangiden, Geb. Borntraeger, Leipzig, 1924, 200.)

Etymology: Modern Latin from Greek *cirrhos*, tawny.

Swarm stage (pseudoplasmodium): Rods 0.8 by 2 to 5 microns.

Fruiting bodies: Elongate, upright, thickened below, slender above, extended to a rounded point, 50 to 100 microns long, 20 microns in diameter at base, light red to flesh-colored. Spores about 1 micron.

Source and habitat: Thaxter (*loc. cit.*), once only on grouse dung, Mass.

Illustrations: Thaxter (*loc. cit.*) Pl. 31, Figs. 25–27.

3. **Chondrococcus megalosporus Jahn. (Beiträge zur botanischen Protistologie.**

I. Die Polyangiden, Geb. Borntraeger, Leipzig, 1924, 86.)

Etymology: Greek *megalos*, large; *sporos*, seed, spore; large spored.

Swarm stage (pseudoplasmodium): Not described.

Fruiting bodies: About 80 to 160 microns wide, rounded, cushion-shaped, dark flesh color. Spores 2 microns.

Source and habitat: Jahn (*loc. cit.*), on stag dung near Berlin.

Illustrations: Jahn (*loc. cit.*) Fig. Y, i to k, p. 87.

4. **Chondrococcus macrosporus** Krzemieniewski. (Acta Soc. Bot. Poloniae, *4*, 1926). According to Krzemieniewski, not to be confused with Zukal's species, *Myxococcus macrosporus* (Ber. d. deutsch Bot. Gesellsch., *15*, 1897, 542.)

Etymology: Greek *makros*, long, large; *sporos*, seed, spore; large-spored.

Swarm stage (pseudoplasmodium): Not described.

Fruiting bodies: Much like *Chondrococcus coralloides*, differing in color and in size of spores. Spores 1.6 to 2.0 microns. Fruiting body yellow or light brown color, with long branches.

Source and habitat: Krzemieniewski (*loc. cit.*), found it first on leaves, later isolated from soil on rabbit dung.

Illustrations: Krzemieniewski (*loc. cit.*) Pl. II, Fig. 19.

5. **Chondrococcus blasticus** Beebe. (Iowa State Col. Jour. Sci., *15*, 1941, 310.)

Etymology: Greek *blastikos*, budding.

Fruiting body: Primary: Spherical to subspherical, usually sessile but occasionally with a short stalk or foot; pale pink to bright salmon pink; 300 to 600 microns in diameter. No outer wall or limiting membrane evident. Develops on sterilized rabbit dung in from 3 to 6 days at room temperature. Secondary: Arising as bud-like growth from the primary fruiting body. Develops into irregularly shaped, finger-, coral- or bud-like protuberance. Seldom branched; occasionally stalked but usually sessile on primary fruiting body until latter is utilized in formation of several secondary fruiting bodies. Deep pink to salmon pink in color. Variable in size and shape; 50 to 150 by 75 to 225 microns. No outer wall or limiting membrane evident.

Spores: Spherical, thick-walled, highly refractile; 1.2 to 1.4 microns in diameter. Held together in the fruiting body by the mass of slime.

Vegetative cells: Long, slender, flexible rods, straight or curved to bent, ends rounded to slightly tapered, Gram-negative. 0.5 to 0.6 by 3.0 to 5.0 microns. Usually found in groups of 2 to 12 lying parallel on the surface of the slimy colony, the group moving as a unit. Motile by a crawling or creeping motion, no flagella.

Vegetative colony: Thin, colorless, transparent at margin; surface broken by many small ridges or veins. Center smooth, slightly thicker, often showing pale pink color. Fruiting bodies first form at or near center, later distributed irregularly on other parts of colony. Margin composed of active vegetative cells.

Physiology: Good growth on mineral salt agar to which has been added such complex carbohydrates as dulcitol, inulin, cellulose, reprecipitated cellulose or starch; starch hydrolyzed, cellulose not destroyed appreciably. Can utilize agar as both C and N sources. Best growth on suspensions of killed bacterial cells in agar. Growth inhibited partially or entirely by arabinose, mannose and maltose.

Source: Goat dung and soil, Ames, Iowa.

Habitat: Soil. Decomposes organic matter, especially bacterial cells in dung.

Illustrations: Beebe (*loc. cit.*) Pl. II, Figs. 5–6, pl. IV, Fig. 18.

6. **Chondrococcus cerebriformis** (Kofler) Jahn. (*Myxococcus cerebriformis* Kofler, Sitzber. d. kais. Akad. Wiss., Wien. Math.-Nat. Klasse, 122

Abt., 1913, 866; Jahn, Beiträge zur botanischen Protistologie. I. Die Polyangiden, Geb. Borntraeger, Leipzig, 1924, 86.)

Etymology: Latin *cerebrum*, brain; *formis*, shape.

Swarm stage (pseudoplasmodium): Rods 4 to 12 microns.

Fruiting bodies: About 1 mm long, clumped masses with swollen upper surface, brain-like, violet rose, often lead-gray. Cysts 100 to 170 microns, without slime envelope. Spores 1.1 to 1.6 microns. Jahn (*loc. cit.*) suggests that this may be *Archangium gephyra*.

Source and habitat: Kofler (*loc. cit.*), on hare dung in the vicinity of Vienna.

Illustrations: Kofler (*loc. cit.*) Pl. 2, Figs. 7 and 8.

7. **Chondrococcus columnaris** (Davis) Ordaland Rucker. (*Bacillus columnaris* Davis, Bull. U. S. Bur. Fisheries, *38*, 1923, 261; Ordal and Rucker, Proc. Soc. Exper. Biol. and Med., *56*, 1944, 18; also see Fish and Rucker, Trans. Amer. Fish. Soc., *73*, 1944 in press; *Cytophaga columnaris* Garnjobst, Jour. Bact., *49*, 1945, 113.)

Etymology: From Latin *columnaris*, rising in the form of a pillar.

Vegetative cells: Flexible, weakly refractive, Gram-negative rods, 0.5 to 0.7 by 4 to 8 microns. Creeping motion observed on solid media, and flexing movements in liquids.

Spores (microcysts): 0.7 to 1.2 microns, spherical to ellipsoidal, occurring on both liquid and solid media.

Physiology: Growth best on 0.5 to 0.9 per cent agar with 0.25 to 0.50 per cent Bactotryptone at pH 7.3. Colonies on tryptone agar yellow, flat and irregular. Edge uneven with swarming apparent. Gelatin liquefied rapidly. No indole. No reduction of nitrates. Starch, cellulose and agar not attacked. Sugars not fermented, but glucose oxidized.

Fruiting bodies on agar not deliquescent, and surrounded by a firm membrane. A peculiar type of fruiting body formed in liquid media. Where organisms are in contact with infected tissues or with scales, produce columnar, sometimes branched, fruiting bodies in which typical spores (microcysts) develop in 7 to 10 days.

Source and habitat: First described as cause of bacterial disease of warm water fishes (Davis, *loc. cit.*) and later in fingerlings of the cold water blue black salmon (*Oncorrhynchus nerka*). Transmissible to salmonid fishes.

Genus III. **Angiococcus** *Jahn.*

(Beiträge zur Protistologie. I. Die Polyangiden, Geb. Borntraeger, Leipzig, 1924, 89.)

A segregate from *Myxococcus* Thaxter.

Diagnosis: Fruiting body consisting of numerous round (disk-shaped) cysts, cyst wall thin, spores within.

Etymology: Greek *angion*, vessel and *kokkos*, coccus (ball).

The type species is *Angiococcus disciformis* (Thaxter) Jahn.

Key to the species of genus **Angiococcus.**

A. Cysts yellow to dark orange-yellow; disk-shaped; 35 microns in diameter
1. *Angiococcus disciformis.*

B. Cysts colorless to yellow; round; up to 15 microns in diameter.
2. *Angiococcus cellulosum.*

1. **Angiococcus disciformis** (Thaxter) Jahn. (*Myxococcus disciformis* Thaxter, Bot., Gaz., *37*, 1904, 412; Jahn, Beiträge zur botanischen Protistologie. I. Die Polyangiden, Geb. Borntraeger, Leipzig, 1924, 89.)

Etymology: Greek *diskos*, a quoit, discus; Latin *formis*, shape.

Swarm stage (pseudoplasmodium): Rods 0.5 to 0.6 by 2 to 3 microns.

Fruiting bodies: Cysts disk-shaped, crowded, sessile, attached by a more or less ragged scar-like insertion, or in masses. Cysts yellowish when young, when old dark orange-yellow, about 35 by 10 microns. Cyst wall distinct, thin, becoming very slightly wrinkled. Spores irregularly spherical, embedded in viscous slime, difficult to see in the ripe cyst.

Source and habitat: Thaxter (*loc. cit.*), dung of muskrat and deer, Massachusetts and New Hampshire. Krzemieniewski (1927, *loc. cit.*), rare in Polish soils.

Illustrations: Thaxter (*loc. cit.*) Pl. 27, Figs. 19–21. Krzemieniewski Acta Soc. Bot. Poloniae, *4*, 1926, Pl. II, Figs. 21–22.

2. **Angiococcus cellulosum** Mishustin. (Microbiology, Moscow, 7, 1938, 427.)

Etymology: Modern Latin *cellulosum*, cellulose.

Fruiting body: Regularly rounded (less frequently extended or angular), 20 to 150 microns in diameter; yellow or pink in color, to drabbish when old. Encysted cells surrounded by a colorless cyst wall or envelope. Usually 1 to 3 short stalks or cystophores up to 10 microns high. Within outer wall are numerous cysts containing resting cells (spores). Cysts have regularly rounded form; unpigmented to yellow; 5 to 15 microns in diameter, average 6 microns. Number of cysts in fruiting body increases with age.

Spores: Cocci (term used is shortened rods) combined into globular aggregations easily broken up. Size not given.

Vegetative cells: 0.4 to 0.5 by 1.5 to 2.0 microns. Cell contents pigmented gray, and of indefinite outline (?).

Vegetative colony: Fairly rapid growth on cellulose with silica gel. Colony has a yellowish cast. Reaches diameter of 1.5 to 2.0 cm after 6 days with center yellowish-pink and margin tinged light pink. Surface moist. Fruiting bodies more numerous at center, but distributed over entire area. Fruiting bodies do not noticeably protrude above the surface of the colony.

Physiology: Cellulose attacked but not completely destroyed. Lower fibers remain intact, but on treatment with hot soda solution they fall spart.

Habitat: Soils.

Genus IV. **Sporocytophaga** *Stanier.*

(Jour. Bact., *40*, 1940, 629.)

Diagnosis: Spherical or ellipsoidal microcysts formed loosely in masses of slime among the vegetative cells. Fruiting bodies absent.

Etymology: Greek *sporos* seed, spore; *kytos* hollow place, cell and *phagein* to eat.

The type species is *Sporocytophaga myxococcoides* (Krzemieniewska) Stanier.

Key to the species of genus **Sporocytophaga.**

I. Microcysts spherical.
  A. Does not utilize starch.
    1. *Sporocytophaga myxococcoides.*
  B. Utilizes starch.
    2. *Sporocytophaga congregata.*

II. Microcysts ellipsoidal.
    3. *Sporocytophaga ellipsospora.*

1. **Sporocytophaga myxococcoides** (Krzemieniewska Stanier. (*Spirochaeta cytophaga* Hutchinson and Clayton, Jour. Agr. Sci., *9*, 1919, 150; *Cytophaga myxococcoides* Krzemieniewska, Arch. Mikrobiol., *4*, 1933, 400; *Cytophaga globulosa* Stapp and Bortels, Cent. f. Bakt., II Abt., *90*, 1934, 47; *Cytophaga hutchinsonii* Imšenecki and Solntzeva, Bull. Acad. Sci. U.S.S.R., Ser. Biol., No. 6, 1936, 1129; not *Cytophaga hutchinsoni* Winogradsky, Ann. Inst. Pasteur, *43*, 1929, 578; Stanier, Jour. Bact., *40*, 1940, 630.)

Etymology: Modern Latin from generic name *Myxococcus*, and *eidos*, like.

Vegetative morphology: Flexible, singly occurring rods, 0.3 to 0.4 micron wide at the center, tapering to both ends. Length 3 to 8 microns according to Krzemieniewska (*loc. cit.*), 2.5 to 5 microns according to Jensen (Proc. Linn. Soc. N. So. Wales, *65*, 1940, 547). May be straight, bent, U-shaped or S-shaped. Show creeping motility (Stapp and Bortels, *loc. cit.*). Stain poorly with ordinary aniline dyes; with Giemsa's stain, the young cells are colored uniformly except for the tips. As the rods shorten and swell to form microcysts, the chromatin becomes concentrated and moves toward the center of the cell, generally in the form of two parallel bands (Krzemieniewska, Acta Soc. Bot. Pol., 7, 1930, 514).

Microcysts: Spherical, 1.3 to 1.6 microns in diameter, covered with a sheath of mucus. According to Krzemieniewska (1930, *loc. cit.*), germination is by emergence of the shortened rod from the sheath, followed by elongation; according to Stapp and Bortels (*loc. cit.*) and Imšenecki and Solntzeva (*loc. cit.*), by a simple elongation of the entire microcyst.

Growth is strictly confined to cellulose. On mineral salts-silica gel plates covered with filter paper, yellow, glistening, slightly mucilaginous patches are produced after a few days. The color gradually assumes a light brownish tinge on aging. The filter paper in these regions is eventually completely dissolved and the patches become translucent.

Ammonia, nitrate, asparagin, aspartic acid and peptone can serve as sources of nitrogen (Jensen, *loc. cit.*).

Strictly aerobic.

Optimum temperature 28 to 30°C.

Source: Isolated from soil.

Habitat: Soil. Decomposes cellulose.

2. **Sporocytophaga congregata** Fuller and Norman. (Jour. Bact., *45*, 1943, 567.)

Etymology: Latin *congrēgo*, to assemble.

Vegetative cells are long, flexuous rods with pointed ends, 0.5 to 0.7 by 5.5 to 8.0 microns. Creeping motility on solid surfaces.

Spores (microcysts): Spherical, 0.7 to 1.1 microns in diameter. Usually occur in localized regions within the colony.

Growth on starch agar is smoky, later turning yellow. Colonies are irregularly round, slightly concave. Edge is smooth and entire at first, later becoming irregular. Marginal and internal swarming may be prominent. The vegetative cells gather into groups and in these regions a large number of spherical spores are found.

Growth on cellulose dextrin agar is pale; colonies are small and concave. Hollowing of the agar is limited to the area of colony growth.

Glucose, galactose, lactose, maltose, sucrose, arabinose, calcium gluconate, starch, cellulose dextrin, pectin, and hemicellulose are utilized. Filter paper is not attacked.

Ammonium, nitrate, and peptone are suitable nitrogen sources.

Indole not formed.

Nitrites not produced from nitrates.

Litmus milk: Growth but no digestion or curd formation.

Highly aerobic.

Optimum temperature 25° to 30°C.

Source: Isolated from soil.

Habitat: Soil. Decomposes organic matter.

3. **Sporocytophaga ellipsospora** (Imšenecki and Solntzeva) Stanier. (*Cytophaga ellipsospora* Imšenecki and Solntzeva, Bull. Acad. Sci. U.S.S.R., Ser. Biol., No. 6, 1936, 1137; Stanier, Bact. Rev., *6*, 1942, 153 and 190.)

Etymology: Greek *ellipsis*, an ellipse, and *sporos*, seed.

Vegetative morphology: Flexible, singly occurring rods, 0.4 micron wide at the center and tapering to both ends. Length 7.5 microns. May be straight, bent, U-shaped, or S-shaped. Show creeping motility.

Microcysts: Oval or somewhat elongated, 0.9 to 1.2 by 1.6 to 1.8 microns Almost always situated in closely-packed aggregates, isolated individual microcysts rare. Germinate by elongation.

Growth is strictly confined to cellulose. On mineral salts-silica gel plates covered with filter paper, orange, glistening, mucilaginous patches are produced. Ultimately the filter paper is completely dissolved and the patches become translucent.

Ammonia, nitrate and peptone can serve as sources of nitrogen.

Strictly aerobic.

Optimum temperature 28° to 30°C.

Source: Isolated from soil.

Habitat: Soil. Decomposes cellulose

ORDER V. SPIROCHAETALES BUCHANAN.*

(Jour. Bact., *3*, 1918, 542.)

Slender, flexuous cell body in the form of a spiral with at least one complete turn, 6 to 500 microns in length. Some forms may show an axial filament, a lateral crista or ridge, or transverse striations; otherwise no significant protoplasmic pattern. Smaller forms may have a lower refractive index than bacteria, and so living organisms can be seen only with dark field illumination. Some forms take aniline dyes with difficulty. Giemsa's stain is uniformly successful. Multiplication by transverse fission. No sexual cycle known. Granules formed by some species in vector hosts. All forms are motile. No organs of locomotion**; motility serpentine or by spinning on the long axis without polarity. Free-living, saprophytic and parasitic.

Key to the families of order **Spirochaetales.**

I. Spirals 30 to 500 microns in length, having definite protoplasmic structures.
Family I. *Spirochaetaceae*, p. 1051.
II. Spirals 4 to 16 microns in length, having no obvious protoplasmic structure.
Family II. *Treponemataceae*, p. 1058.

FAMILY I. SPIROCHAETACEAE SWELLENGREBEL.

(Ann. Inst. Past., *21*, 1907, 581.)

Coarse spiral organisms, 30 to 500 microns in length, having definite protoplasmic structures. Found in stagnant, fresh or salt water and in the intestinal tract of bivalve molluscs (*Lamellibranchiata*).

Key to the genera of family **Spirochaetaceae.**

I. No obvious periplast membrane and no cross-striations.
Genus I. *Spirochaeta*, p. 1051.
II. Periplast membrane present. Cross-striations prominent in stained specimens.
A. Free-living in marine ooze.
Genus II. *Saprospira*, p. 1054.
B. Parasitic on lamellibranch molluscs. Crista prominent.
Genus III. *Cristispira*, p. 1055.

Genus I. Spirochaeta *Ehrenberg.*

(Ehrenberg, Abhandl. Berl. Akad., 1833, 313; *Spirochoeta* Dujardin, Hist. nat. des Zoophytes, 1841, 209; *Spirochaete* Cohn, Beitr. z. Biol. d. Pflanz., *1*, Heft 1, 1872,

* Originally prepared by Prof. D. H. Bergey, Philadelphia, Pa., October, 1922. Revised by Prof. E. G. D. Murray, McGill University, Montreal, P. Q., Canada, December, 1938. Further revision by Dr. G. H. Robinson, Wm. H. Singer Memorial Research Laboratory of the Allegheny General Hospital, Pittsburgh, Pa., September, 1943. Appendices prepared by Mrs. Eleanore Heist Clise, Geneva, N. Y., September, 1943.

** Recent photographs taken with the electron microscope indicate the presence of structures resembling flagella (Mudd, Polevitzky and Anderson, Jour. Bact., *46*, 1943, 15). Whether these can be considered as organs of locomotion awaits decision. At present it seems best to confine descriptions of structure to features seen by use of the oil immersion lens.

180; *Ehrenbergia* Gieszczykiewicz, Bull. Acad. Polonaise d. Sci. et Lettres, Cl. Sci. Math. et Nat., Sér. B, 1939, 24.)

Non-parasitic, with flexible, undulating body and with or without flagelliform tapering ends. Protoplast wound spirally around a well-defined axial filament. No obvious periplast membrane and no cross-striations. Motility by a creeping motion. Primary spiral permanent. Free-living in fresh or sea water slime, especially in the presence of H_2S. Common in sewage and foul waters.

The type species is *Spirochaeta plicatilis* Ehrenberg.

Key to the species of genus **Spirochaeta.**

I. Large spirals with rounded ends.
   1. *Spirochaeta plicatilis.*
   2. *Spirochaeta marina.*
   3. *Spirochaeta eurystrepta.*

II. Smaller spirals with pointed ends.
   4. *Spirochaeta stenostrepta.*
   5. *Spirochaeta daxensis.*

1. **Spirochaeta plicatilis** Ehrenberg. (Ehrenberg, Die Infusionstierchen, 1838, 83; *Spirillum plicatile* Dujardin, Infus., *1*, 1841, 225; *Spirulina plicatilis* Cohn, Nova Acta Acad. Caes. Leop. Carol., *24*, I, 1853, 125; *Spirochaete plicatilis* Cohn, Beitr. z. Biol. d. Pflanz., *1*, Heft 2, 1872, 180; *Spirillum portae* Mantegazza, Giorn. Ist. Lomb., *3*, p. 487, according to DeToni and Trevisan, in Saccardo, Sylloge Fungorum, *8*, 1889, 1006; *Spirochaeta plicatilis plicatilis* Zuelzer, Arch. f. Protistenk., *24*, 1912, 17; *Ehrenbergia plicatilis* Gieszczykiewicz, Bull. Acad. Polonaise d. Sci. et Lettres, Cl. Sci. Math. et Nat., Sér. B, 1939, 24.) From Latin, folded.

Cylindrical: 0.5 to 0.75 by 100 to 500 microns, with blunt ends.

Spiral amplitude: 2.0 microns, regular. Spiral depth: 1.5 microns, regular. Waves, several, large, inconstant, irregular.

Axial filament distinct in stained specimens, consisting of chitin or cutin-like substance. Flexible, elastic.

Division transverse.

Stains violet by Giemsa's stain and gray by iron-hemotoxylin.

Cytoplasmic spirals stain with eosin, rubin, etc. Contain volutin granules.

Trypsin digestion: Axial filament resistant.

Bile salts (10 per cent): Becomes shadowy, pale, but is not dissolved.

Saponin (10 per cent): Lives 30 minutes. Later becomes shadowy, but is not dissolved.

Grows best under low oxygen tension.

Optimum temperature 20° to 25°C.

Habitat: Free-living in fresh or salt water.

2. **Spirochaeta marina** Zuelzer. (*Spirochaeta plicatilis marina* Zuelzer, Arch. f. Protistenk., *24*, 1912, 17; Zuelzer, *ibid.*, 51.) From Latin, of the sea.

Probably a subspecies or variant of *Spirochaeta plicatilis.*

Cylindrical, 0.5 by 100 to 200 microns with blunt ends.

Axial filament present. Flexible, elastic.

Division transverse.

Contains smaller and more irregularly distributed volutin granules than *Spirochaeta plicatilis.* Cytoplasmic spirals stain.

Grows best at low oxygen tension.

Optimum temperature 20°C.

Habitat: Sea water.

3. **Spirochaeta eurystrepta** Zuelzer. (*Spirochaeta plicatilis eurystrepta* Zuelzer, Arch. f. Protistenk., *24*, 1912, 17;

Zuelzer, *ibid.*, 51.) From Greek, broadly twisted.

Probably a subspecies or variant of *Spirochaeta plicatilis.*

Cylindrical: 0.5 micron in thickness and up to 300 microns in length.

Spiral amplitude: More shallow than spirals of *Spirochaeta plicatilis* with blunt ends.

Axial filament present. Flexible, elastic.

Division transverse.

Fewer volutin granules than in *Spirochaeta plicatilis.* Cytoplasmic spirals stain.

Optimum temperature 20°C.

Habitat: Swamp water and in grossly polluted water containing H_2S.

4. **Spirochaeta stenostrepta** Zuelzer. (Zuelzer, Arch. f. Protistenkunde, *24*, 1912, 16; *Treponema stenostrepta* Enderlein, Bakterien-Cyclogenie, 1925, 253.) From Greek, narrowly twisted.

Cylindrical: 0.25 micron in thickness and 20 to 60, occasionally up to 200, microns in length, with pointed ends.

Spiral amplitude very narrow with steep windings.

Axial filament present. Flexible, elastic.

Division transverse.

Fewer volutin granules than in *Spirochaeta plicatilis.*

Cytoplasmic spirals stain.

Optimum temperature 20°C.

Habitat: Water containing H_2S.

5. **Spirochaeta daxensis** Cantacuzène. (Compt. rend. Soc. Biol., Paris, *68*, 1910, 75.) Named for Dax, a watering place in France.

Large spirals: 0.5 to 2.5 by 30 to 100 microns, possessing a longitudinal chromatin filament, and tapering at the ends.

They are flattened and exhibit a double series of curls, smaller waves being superimposed on larger undulations.

Optimum temperature 44° to 52°C.

Source: Found in water of hot spring of Dax (52° to 56°C).

Habitat: Hot springs.

Appendix: The following species may belong in this genus. Descriptions are usually inadequate.

Spirochaeta agilis Adelmann. (Cent. f. Bakt., I Abt., Orig., *88*, 1922, 413.) From mud from the harbor at Kiel. Original culture had a weak odor of hydrogen sulfide.

Spirochaeta aurantia Vinzent. (Compt. rend. Soc. Biol., Paris, *95*, 1926, 1472.) From drain water. Forms small yellowish-orange colonies on agar after 5 to 8 days. Shows involution forms. This species definitely does not belong in the genus *Spirochaeta*, although it is placed here for the present. Its description suggests that it may belong among the vibrios.

Spirochaeta flexibilis Nägler. (Cent. f. Bakt., I Abt., Orig., *50*, 1909, 445.) From the mud of a lake.

Spirochaeta fulgurans Dobell. (Arch. f. Protistenk., *26*, 1912, 117.) From water of the river Granta at Cambridge. May be a synonym of *Spirochaeta stenostrepta.*

Spirochaeta gigantea Warming. (Warming, Videnskabl. Meddel. Naturh. Foren., Copenhagen, 1875, 70; *Spirillum giganteum* Trevisan, I generi e le specie delle Batteriacee, 1889, 24; not *Spirillum giganteum* Migula, Syst. d. Bakt., *2*, 1900, 1025.) Large, 3 microns in diameter. Inadequately described and possibly not a spirochaete.

Spirochaeta graminea Zuelzer. (Zuelzer, 1925, in Prowazek, Handb. d. path. Protoz., *3*, 1931, 1670.) From an infusion of herbs. Size 0.25 by 100 microns. From rivers and marshes where it digests cellulose.

Spirochaeta graminea marina Zuelzer. (Cent. f. Bakt., I Abt., Orig., *96*, 1925, 426.) From sea water.

Spirochaeta icterogenes marina Zuelzer.

(Cent. f. Bakt., I Abt., Orig., *96*, 1925, 426.) From sea water.

Spirochaeta minima Dobell. (Dobell, Arch. f. Protistenk., *26*, 1912, 117; not *Spirochaeta minima* Pettit, Contribution à l'Étude des Spirochétidés, Vanves, II, 1928, 187 (*Treponema minimum* Beaurepaire-Aragão and Vianna, Mem. Inst. Oswaldo Cruz, *5*, 1913, 211).) One of the smallest known *Spirochaeta*, 0.5 by 2.0 to 2.5 microns. From water of the river Granta at Cambridge. Similar to *Spirochaeta fulgurans*.

Spirochaeta vivax (Dobell) Zuelzer. (*Treponema vivax* Dobell, Arch. f. Protistenk., *26*, 1912, 117; Zuelzer, 1925, in Prowazek, Handb. d. path. Protoz., *3*, 1931, 1669.) From fresh water of the river Granta at Cambridge.

Spirochaete kochii Trevisan. (Spirochaete des Wollsteiner See, Koch, in Cohn, Beitr. z. Biol. d. Pflanzen, *2*, Heft 3, 1877, 420; Trevisan, Batter. Ital., 1879, 26; *Spirillum kochii* Trevisan, I generi e le specie delle Batteriacee, 1889, 24.) From water.

Spirochaete schroeteri Cohn. (Jahresber. d. Schles. Gesellch. f. 1883, 198; quoted from Schroeter, in Cohn, Kryptog. Flora v. Schlesien, *3*, 1, 1889, 168; *Spirillum schroeteri* Cohn, quoted from DeToni and Trevisan, in Saccardo, Sylloge Fungorum, *8*, 1889, 1007.) Similar to *Spirochaete cohnii*. From cellar walls.

Genus II. Saprospira *Gross.*

(Mittheil. Zool. Stat. zu Neapel, *20*, 1911, 190.)

Spiral protoplasm without evident axial filament. Spirals rather shallow. Transverse markings or septa (?) seen in unstained and stained specimens. Periplast membrane distinct. Motility active and rotating. Free-living in marine ooze.

The type species is *Saprospira grandis* Gross.

1. **Saprospira grandis** Gross. (Mitteil. Zool. Station zu Neapel, *20*, 1911, 190.) From Latin, great.

Cylindrical, 1.2 by 80 microns in length, with obtuse ends.

Spiral amplitude is 24 microns.

Waves large, inconstant, shallow, irregular, 3 to 5 in number, sometimes almost straight.

Axial filament absent.

Cross-striations present.

Membrane distinct.

Division transverse.

Flexible, elastic.

Crista absent.

Terminal spiral filament absent.

Highly motile end portion absent.

Trypsin digestion.

Source: Found in intestinal tract of the oyster.

Habitat: Free-living in foraminiferous sand.

2. **Saprospira puncta** Dimitroff. (Jour. Bact., *12*, 1926, 146.) From Latin, pitted.

Large spirals: 1.0 by 86 microns with pointed ends.

The spiral amplitude is 4 to 8 microns.

The average number of turns is 3.

Axial filament absent.

Cross-striations present.

Membrane distinct.

Division transverse.

Source: Found in oysters.

3. **Saprospira lepta** Dimitroff. (Jour. Bact., *12*, 1926, 144.) From Latin, small.

Large spirals: 0.5 by 70.0 microns, with pointed ends.

The spiral amplitude ranges from 5 to 13 microns.

The spiral width varies from 1.6 to 4.8 microns.

The average number of turns is 6.

Axial filament absent.

Cross-striations present.

Membrane distinct.

Division transverse.

Source: Found in oysters in Baltimore, Maryland.

Appendix: The following species have been placed in this genus.

Saprospira flexuosa Dobell. (Arch. f. Protistenk., *26*, 1912, 117.) Isolated once from water of the river Granta at Cambridge.

Saprospira nana Gross. (Mittheil. Zool. Sta. zu Neapel, *20*, 1911, 188.) From foraminiferous sand.

Genus III. Cristispira *Gross.*

(Mittheil. Zool. Stat. zu Neapel, *20*, 1910, 41.)

Flexuous cell bodies in coarse spirals, 28 to 120 microns in length. Characterized by a crista or thin membrane of varying prominence on one side of the body extending the entire length of the organism. Cross-striations. Actively motile. Found in the intestinal tract of molluscs.

The type species is *Cristispira balbianii* (Certes) Gross.

1. **Cristispira balbianii** (Certes) Gross. (*Trypanosoma balbianii* Certes, Bull. Soc. Zool. de France, *7*, 1882, 347; *Spirochaeta balbianii* Swellengrebel, Ann. Inst. Past., *21*, 1907, 562; *Spirochaete balbianii* Borrel and Cernovodeanu, Compt. rend. Soc. Biol., Paris, *62*, 1907, 1102; Gross, Cent. f. Bakt., I Abt., Orig., *65*, 1912, 90.)

Cylindrical: 1.0 to 3.0 by 40 to 120 microns, with obtuse ends.

Spiral amplitude is 8 microns. Spiral depth is 1.6 microns. Waves 2 to 5, sometimes more, large, irregular, shallow.

Axial filament absent.

Cross-striations present.

Membrane distinct.

Flexible, elastic.

Crista present, a ridge-like membrane making one to two complete turns.

Terminal spiral filament absent. Highly motile end portion absent.

Stains: Cell membrane behaves like chitin or cutin substance. Stains violet by Giemsa's solution, and light gray by iron-hemotoxylin.

Trypsin digestion: Membrane resistant, crista and striations disappear.

Bile salt (10 per cent): Crista quickly dissolves.

Saponin (10 per cent): Crista becomes fibrillar, then indistinct.

Source: From the crystalline style of oysters.

Habitat: Parasitic in alimentary tract of shell-fish.

2. **Cristispira anodontae** (Keysselitz) Gross. (*Spirochaeta anodontae* Keysselitz, Arb. a. d. kaiserl. Gesundheitsamte, *23*, 1906, 566; Gross, Cent. f. Bakt., I Abt., Orig., *65*, 1912, 900.) From M.L., mussels.

0.8 to 1.2 by 44 to 88 microns with sharply pointed ends; flattened and possessing an undulating membrane. The periplast is fibrillar in appearance and there is a dark granule at each end of the undulating membrane. The chromatin material is distributed in the form of globules or elongated bands.

Large spirals: The average width of the spiral is 2 microns. The average wave length is 8 microns.

The number of complete turns ranges from 5 to 11.

Habitat: Found in the crystalline style of fresh water mussels, *Anodonta cygnea* and *A. mutabilis*, also in intestinal tract of oysters.

3. **Cristispira pinnae** (Gonder) Bergey et al. (*Spirochaete pinnae* Gonder, Cent. f. Bakt., I Abt., Orig., *47*, 1908, 491; *Spirochaeta pinnae* Schellack, Arb. a. d.

kaiserl. Gesundheitsamte, *30*, 1909, 379; Bergey et al., Manual, 1st ed., 1923, 423.) From Latin, of a mussel.

Spirals: 0.5 to 3.0 by 10 to 60 microns, round in section with blunt ends, the one being slightly more pointed than the other.

They have a ridge or comb running along one side but no terminal filaments.

Cross-striations distinct.

The chromatin granules are grouped in fours.

An undulating membrane can be demonstrated.

Source: Found in the intestinal canal of the scallop (*Pecten jacobaeus*).

Habitat: From the crystalline style of molluscs.

Appendix: Additional species which appear to belong in this genus are:

Cristispira acuminata (Schellack) Ford. (*Spirochaeta acuminata* Schellack, Arb. kais. Gesundheitsamte, *30*, 1909, 379; not *Spirochaeta acuminata* Castellani, Brit. Med. Jour., *2*, 1905, 1330; Ford, Textb. of Bact., 1927, 939.) From the crystalline style of a mollusc, *Tapes laeta*.

Cristispira cardii-papillosi (Schellack) Ford. (*Spirochaeta cardii-papillosi* Schellack, Arb. kais. Gesundheitsamte, *30*, 1909, 379; Ford, Textb. of Bact., 1927, 939.) From the crystalline style of a mollusc, *Cardium papillosum*.

Cristispira chamae (Schellack) Noguchi. (*Spirochaeta chamae* Schellack, Arb. kais. Gesundheitsamte, *30*, 1909, 379; Noguchi, Jour. Exp. Med., *27*, 1918, 583.) From the crystalline styles of molluscs, *Chama spp.*

Cristispira gastrochaenae (Schellack) Ford. (*Spirochaeta gastrochaenae* Schellack, Arb. kais. Gesundheitsamte, *30*, 1909, 379; Ford, Textb. of Bact., 1927, 940.) From a shellfish, *Gastrochaena dubia*. Constant length 29 microns.

Cristispira helgolandica Collier. (Cent. f. Bakt., I Abt., Orig., *86*, 1921, 132.) Found three times in the body fluid of an echinoderm, *Asterias rubens*, in the North sea. Average length 68 microns. Named for the place where the investigation was made (Helgoland).

Cristispira interrogationis Gross. (Mittheil. Zool. Station zu Neapel, *20*, 1910, 41.) From the intestinal canal of the scallop, *Pecten jacobaeus*.

Cristispira limae (Schellack) Ford. (*Spirochaeta limae* Schellack, Arb. kais. Gesundheitsamte, *30*, 1909, 379; Ford, Textb. of Bact., 1927, 939.) From the crystalline styles of molluscs, *Lima spp.* Similar to *Cristispira balbianii*.

Cristispira mactrae (Prowazek) Ford. (*Spirochaeta mactrae* Prowazek, Arch. f. Schiffs- u. Tropenhyg., *14*, 1910, 297; Ford, Textb. of Bact., 1927, 940.) From the digestive tract of a shellfish, *Mactra sulcataria*.

Cristispira mina Dimitroff. (Jour. Bact., *12*, 1926, 159.) Found in oysters.

Cristispira modiolae (Schellack) Noguchi. (*Spirochaeta modiolae* Schellack, Arb. kais. Gesundheitsamte, *30*, 1909, 379; Noguchi, Jour. Exp. Med., *27*, 1918, 583.) Found in mussels and oysters.

Cristispira ostreae (Schellack) Noguchi. (*Spirochaeta ostreae* Schellack, Arb. kais. Gesundheitsamte, *30*, 1909, 379; Noguchi, Jour. Exp. Med., *27*, 1918, 583.) From the crystalline style of the oyster, *Ostrea edulis*. Identical with *Cristispira anodontae* Gross.

Cristispira pachelabrae de Mello. (Compt. rend. Soc. Biol., Paris, *84*, 1921, 241.) From the digestive tract of a shellfish, *Pachelabra moestra*.

Cristispira parvula Dobell. (Arch. f. Protistenk., *26*, 1912, 117.) From the crystalline style of a mollusc, *Venus (Meretrix) castra*, in Ceylon. The smallest *Cristispira* known—0.4 to 0.5 by 20 to 45 microns.

Cristispira pectinis Gross. (Mittheil. Zool. Sta. zu Neapel, *20*, 1910, 41.) From the digestive tract of a scallop, *Pecten jacobaeus*. Identical with *Cristispira balbianii* Gross.

Cristispira polydorae Mesnil and Caul-

lery. (Compt. rend. Soc. Biol., Paris, *79*, 1916, 1118; *Cristispirella polydorae* Hollande, Compt. rend. Acad. Sci. Paris, *172*, 1921, 1696). From a marine annelid, *Polydora flava*.

Cristispira pusilla (Schellack) Ford. (*Spirochaeta pusilla* Schellack, Arb. kais. Gesundheitsamte, *30*, 1909, 379; Ford, Textb. of Bact., 1927, 940.) From the digestive tract of a mussel, *Anodonta mutabilis*.

Cristispira saxicavae (Schellack) Ford. (*Spirochaeta saxicavae* Schellack, Arb. kais. Gesundheitsamte, *30*, 1909, 379; Ford, Textb. of Bact., 1927, 940.) From the crystalline style of a mollusc, *Saxicava arctica*.

Cristispira spiculifera (Schellack) Dimitroff. (*Spirochaeta spiculifera* Schellack, Arb. kais. Gesundheitsamte, *30*, 1909, 379; Dimitroff, Jour. Bact., *12*, 1926, 157.) Found in mussels.

Cristispira tapetos (Schellack) Gross. (*Spirochaeta tapetos* Schellack, Arb. kais. Gesundheitsamte, *30*, 1909, 379; Gross, Cent. f. Bakt., I Abt., Orig., *65*, 1912, 84.) From the crystalline style of a mollusc, *Tapes decussata*.

Cristispira tenua Dimitroff. (Jour. Bact., *12*, 1926, 160.) Found in oysters.

Cristispira veneris Dobell. (Quart. Jour. Microsc. Sci., London, *54*, 1910–1911, 507 and *ibid.*, *56*, 1911, Part 3.) From a clam, *Venus* (*Meretrix*) *castra*, in Ceylon. Identical with *Cristispira balbianii* Gross.

Cristispirella caviae Hollande. (Compt. rend. Acad. Sci., Paris, *172*, 1921, 1693.) From the intestine of a guinea pig. Probably a protozoan. Evidently the same as *Heliconema* (see appendix to *Borrelia*). Both *Cristispirilla polydorae* and *Cristispirella caviae* have characteristics at variance with accepted ideas of spirochaetes.

Spirochaeta solenis Fantham. (Ann. Trop. Med. and Parasitol., *5*, 1911, 479.) A parasite of a mollusc, *Solen ensis*.

FAMILY II. TREPONEMATACEAE SCHAUDINN.

(Deutsche med. Wochnschr., *31*, 1905, 1728.)

Coarse or slender spirals, 4 to 16 microns in length; longer forms due to incomplete or delayed division. Protoplasm with no obvious structural features. Some may show terminal filaments. Spirals regular or irregular, flexible or comparatively rigid. Some visible only with dark field illumination. Parasitic on vertebrates with few exceptions. Some pathogenic. Many can be cultivated.

Key to the genera of family **Treponemataceae.**

I. Stains easily with ordinary aniline dyes.

Genus I. *Borrelia*, p. 1058.

II. Stain with difficulty except with Giemsa's stain and silver impregnation.

A. Strict anaerobes.

Genus II. *Treponema*, p. 1071.

B. Aerobes.

Genus III. *Leptospira*, p. 1076.

Genus I. **Borrelia*** *Swellengrebel.*

(Swellengrebel, Ann. Inst. Past., *21*, 1907, 582; *Spiroschaudinnia* Sambon, in Manson, Tropical Diseases, August, 1907, 833; *Cacospira* Enderlein, Sitzber. Ges. Naturf. Freunde, Berlin, 1917, 309; *Entomospira* Enderlein, *ibid.*; *Spironema* Bergey et al., Manual, 1st ed., 1923, 424; not *Spironema* Vuillemin, Compt. rend. Acad. Sci. Paris, *140*, 1905, 1567; *Spirochaeta* Gieszczykiewicz, Bull. Acad. Polonaise d. Sci. et Lettres, Cl. Sci. Math. et Nat., Sér. B, 1939, 24.)

Length 8 to 16 microns. Coarse, shallow, irregular, with a few obtuse angled spirals. Generally taper terminally into fine filaments. Stain easily with ordinary aniline dyes. Refractive index approximately the same as that of true bacteria. Parasitic upon many forms of animal life. Some are pathogenic for man, other mammals and birds. Generally hematophytes are found on mucous membranes. Some are transmitted by the bites of arthropods.

The type species is *Borrelia anserina* (Sakharoff) Bergey et al.

1. **Borrelia anserina** (Sakharoff) Bergey et al. (*Spirochaeta anserina* Sakharoff, Ann. Inst. Past., *5*, 1891, 564; *Spirillum anserum* (sic) Sternberg, Man. of Bact., 1893, 499; *Spirillum anserinum* Macé, Traité Pratique de Bact., 4th ed., 1901, 1060; *Spirochaete anserina* Macé, *ibid.*; *Spiroschaudinnia anserina* Castellani and Chalmers, Man. Trop. Med., 2nd ed., 1913, 403; *Spironema anserina* Noguchi, Jour. Exp. Med., *27*, 1918, 584; Bergey et al., Manual, 2nd ed., 1925, 435; *Treponema anserina* Noguchi, in Jordan and Falk, Newer Knowledge Bact. and Immun., 1928, 456.) From Latin, pertaining to geese.

Synonyms: *Spirochaeta marchouxi* Nuttall, Epidemiol. Soc., London, *24*, 1904, 12 (Spirille de la poule, Marchoux and Salimbeni, Ann. Inst. Past., *17*, 1903, 569; *Spirochaeta gallinarum* Stephens and Christopher, Practical Study of Malaria and Other Blood Parasites, Liverpool, 1905; *Borrelia gallinarum* Swellengrebel, Ann. Inst. Past., *21*, 1907, 623; *Spirochaete gallinarum* Lehmann and Neumann, Bakt. Diag., 4 Aufl., *2*, 1907, 623; *Spironema gallinarum* Gross, Cent. f. Bakt., I Abt., Orig., *65*, 1912, 92; *Spiroschaudinnia marchouxi* Castellani and Chalmers, Man. Trop. Med., 2nd ed., 1913, 403; *Spironema marchouxi* Ford,

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* Further revision of the genus by Prof. E. G. D. Murray, McGill Univ., Montreal, P. Q., Canada, April, 1947. Reviewed by Dr. Gordon E. Davis, Rocky Mountain Laboratory, U.S.P.H.S, Hamilton, Montana.

Textb. of Bact., 1927, 955; *Spirochaeta gallinae* Ford, *idem*; *Treponema gallinarum* Noguchi, in Jordan and Falk, Newer Knowledge Bact. and Immun., 1928, 461; *Treponema marchouxi* Gay et al., Agents of Disease and Host Resistance, 1935, 1077). The cause of septicaemia in chickens.

Spirochaeta granulosa penetrans Balfour, Jour. Trop. Med. and Hyg., *10*, 1907, 153 (*Spiroschaudinnia granulosa* Balfour, Jour. Trop. Veter., Calcutta, *5*, 1910, 309; *Spironema granulosa* Ford, Textb. of Bact., 1927, 957). From spirochetosis of fowls in Sudan.

Spirochaeta nicollei Brumpt, Bull. Soc. Path. Exot., *2*, 1909, 285 and/or Précis de Parasitol., Paris, 1st ed., 1910 (Galli-Valerio, Cent. f. Bakt., I Abt., Orig., *50*, 1909, 189 and *61*, 1912, 529; *Spironema nicollei* Ford, Textb. of Bact., 1927, 958; *Treponema nicollei* Gay et al., Agents of disease and Host Resistance, 1935, 1077). From spirochetosis of geese in Tunisia.

Spirochaeta neveuxi Brumpt, Bull. Soc. Path. Exot., *2*, 1909, 285 (*Spiroschaudinnia neveuxii* Castellani and Chalmers, Man. Trop. Med., 2nd ed., 1913, 404; *Spironema neveuxi* Ford, Textb. of Bact., 1927, 958; *Treponema neveuxi* Gay et al., Agents of Disease and Host Resistance, 1935, 1077). The cause of fowl spirochetosis in Senegal.

Spirochaeta gallinarum var. *hereditaria* Neumann and Mayer, in Lehmann, Med. Atlanten, *11*, 1914, 276. A North African strain of fowl spirochetosis.

Borrelia pullorum Redowitz, Amer. Jour. Med. Technol., *2*, 1936, 91. From diseased chickens.

Spirochaeta anatis Parrot, Bull. Soc. Path. Exot., *13*, 1920, 647. Pathogenic for domestic ducks in Algeria.

Morphology: 0.25 to 0.3 by 8 to 20 microns, averaging about 1 spiral per micron.

Actively motile, with lashing movements.

Stains readily with aniline dyes and Giemsa's stain.

Cultivation: Can be cultivated in Noguchi's ascitic fluid-rabbit kidney medium.

Immunology: Antigenically distinct from species found in mammals.

Arthropod vectors: Transmitted by the bites of ticks (*Argas persicus*, *A. miniatus*, *A. reflexus* and *Ornithodoros moubata*.)

Pathogenic for birds but not for mammals.

Source: From blood of infected geese, ducks, fowls and vector ticks.

Habitat: The cause of spirochetosis of fowls.

2. **Borrelia recurrentis** (Lebert) Bergey et al. (Obermeier, Berlin. klin. Wochschr., 1873, 152; *Protomycetum recurrentis* Lebert, Ziemssen's Handbuch, *2*, 1874, 267; *Spirochaete obermeieri* Cohn, Beitr. z. Biol. d. Pflanzen, *1*, Heft 3, 1875, 196; *Spirillum obermeieri* Zopf, Die Spaltpilze, 3 Aufl., 1885, 71; *Spirochaeta obermeieri* Migula, in Engler and Prantl, Die natürl. Pflanzenfam., *1*, 1a, 1895, 35; *Spirochaete recurrentis* Lehmann and Neumann, Bakt. Diag., 4 Aufl., *2*, 1907, 621; *Spirochaeta recurrentis* Castellani and Chalmers, Man. Trop. Med., 1st ed., 1910, 305; *Spironema recurrentis* Gross, Cent. f. Bakt., I Abt., Orig., *65*, 1912, 85; *Spiroschaudinnia recurrentis* Castellani and Chalmers, Man. Trop. Med., 2nd ed., 1913, 398; *Spironema obermeieri* Park and Williams, Pathogenic Microorganisms, 6th ed., 1917, 513; *Cacospira recurrentis* Enderlein, Sitzungsber. d. Gesellsch. naturf. Freunde, 1917, 313; *Treponema recurrentis* Brumpt, Nouveau Traité de Médecine, Paris, *4*, 1922, 508; *Treponema obermeieri* Brumpt, *ibid.*; *Cacospira obermeieri* Enderlein, Bakterien-Cyclogenie, 1925, 254; Bergey et al., Manual, 2nd ed., 1925, 433; *Spirillum recurrentis* Ford, Textb. of Bact., 1927, 948; *Spiroschaudinnia obermeieri* Ford, *ibid.*) From Latin, recurring.

Cylindrical or slightly flattened, 0.35 to 0.5 by 8 to 16 microns, with pointed ends.

Spiral amplitude 1.5 microns.

Spirals large, wavy, inconstant, about 5 in number.

Terminal finely spiral filaments present.

Highly motile end portion absent.

Motility: By active cork-screw motion without polarity. Lashing movements common in drawn blood.

Stains with common aniline dyes. Gram-negative. Violet with Giemsa's stain.

Bile salts (10 per cent): Disintegration complete.

Saponin (10 per cent): Immobilized in 30 minutes, then broken up in a few hours. In some a skeletal structure remains.

Cultivation: Can be cultured in ascitic or hydrocoel fluid to which a piece of sterile rabbit kidney is added. Optimum reaction pH 7.2 to 7.4.

Immunology: Serum does not agglutinate *Borrelia duttoni.*

Accidental and experimental transmission by conjunctival sac and skin abrasions.

Disease in experimental animals (small rodents after monkey passage) mild.

Arthropod vector: Louse (*Pediculus humanus*) which exhibits normal transmission from the 16th to the 28th day. Found in the bed-bug (*Cimex lectularius*) and ticks, but not transmitted by them. No evidence of hereditary transmission in the louse.

Habitat: The cause of European relapsing fever. Transmissible to man, monkeys, mice and rats.

3. **Borrelia duttonii** (Novy and Knapp) Bergey et al. (Dutton and Todd, British Med. Jour., *2*, 1905, 1259; *Spirillum duttoni* Novy and Knapp, Jour. Infect. Dis., *3*, March 18, 1906, 296; *Spirochaeta duttoni* Breinl, Lancet, *1*, June 16, 1906, 1690; *Spirochaete duttoni* Lehmann and Neumann, Bakt. Diag., 4 Aufl., *2*, 1907, 623; *Spironema duttoni* Gross, Cent. f. Bakt., I Abt., Orig., *65*, 1912, 94; *Spirochaeta Microspironema duttoni* Duboscq and Lebailly, Compt. rend. Acad. Sci., *154*, 1912, 662; *Spiroschaudinnia duttoni* Castellani and Chalmers, Man. Trop. Med., 2nd ed., 1913, 399; *Treponema duttoni* Brumpt, Nouveau Traité de Médecine, Paris, *4*, 1922, 497; *Cacospira duttoni* Enderlein, Bakterien-Cyclogenie, 1925, 254; Bergey et al., Manual, 2nd ed., 1925, 434.) Named for Dutton, who discovered this organism.

Morphology: Similar to *Borrelia recurrentis.*

Cultivation: Growth occurs under anaerobic conditions in serum water, hydrocoel or ascitic fluid to which a piece of sterile rabbit kidney is added.

Immunology: This organism is antigenically distinct from other causes of relapsing fever.

Pathogenic for mice and rats. Disease in small rodents and many other experimental animals very severe.

Arthropod vector: This species is transmitted to man through the bite of the tick (*Ornithodoros moubata*) by fecal contamination of the bite. In the tick the organism goes through some granulation or fragmentation phenomenon, the nature of which is not understood. Hereditary transmission to at least the third generation of the tick. Not transmitted by the louse.

Habitat: The cause of Central and South African relapsing fever.

4. **Borrelia kochii** (Novy) Bergey et al. (*Spirochaeta kochi* Novy, Proc. Path. Soc. Philadel., N. S. *10*, 1907, 1; *Spirochaeta rossi* Nuttall, Jour. Roy. Inst. Pub. Health, London, *16*, 1908, 385; *Spiroschaudinnia rossii* Castellani and Chalmers, Man. Trop. Med., 2nd ed., 1913, 400; *Spironema kochii* Noguchi, Jour. Exp. Med., *27*, 1918, 584; *Treponema kochi* Brumpt, Nouveau Traité de Médecine, Paris, *4*, 1922, 497; *Treponema rossi* Brumpt, *ibid.*; Bergey et al., Manual, 2nd ed., 1925, 434; *Borrelia rossi* Steinhaus, Insect Microbiology, 1946, 452.)

Named for Koch, who first observed spirochetes in East African relapsing fever.

Morphology: Similar to that of *Borrelia recurrentis*.

Cultivation: Same as for *Borrelia recurrentis*.

Immunology: Antigenically distinct from both *Borrelia recurrentis* and *B. duttonii*.

Pathogenic for mice and rats.

Arthropod vector: No record.

Habitat: The cause of African relapsing fever.

5. **Borrelia novyi** (Schellack) Bergey et al. (Spirochaete from relapsing fever, Norris, Pappenheimer and Flournoy, Jour. Inf. Dis., *3*, 1906, 266; *Spirochaeta novyi* Schellack, Arb. kaiserl. Gesundheitsamte, *27*, 1907, 199 and 364; *Spironema novyi* Gross, Archiv f. Protistenk., *24*, 1912, 115; *Spiroschaudinnia novyi* Castellani and Chalmers, Man. Trop. Med., 2nd ed., 1913, 400; *Treponema novyi* Brumpt, Nouveau Traité de Médecine, Paris, *4*, 1922, 508; *Cacospira novyi* Enderlein, Bakterien-Cyclogenie, 1925, 254; Bergey et al., Manual, 2nd ed., 1925, 434.) Named for Novy, the American bacteriologist.

Morphology: Similar to that of *Borrelia recurrentis*.

Cultivation: Same as for *Borrelia recurrentis*.

Immunology: Antigenically distinct from other relapsing fever organisms.

Pathogenic for monkeys, white rats and white mice.

Arthropod vector: Unknown.

Habitat: Recovered from a patient in Bellevue Hospital, New York. Origin of infection unknown.

6. **Borrelia berbera** (Sergent and Foley) Bergey et al. (*Spirochaeta berbera* Sergent and Foley, Ann. Inst. Past., *24*, 1910, 337; *Spiroschaudinnia berbera* Castellani and Chalmers, Man. Trop. Med., 2nd ed., 1913, 402; *Spironema berbera* Noguchi, Jour. Exp. Med., *27*, 1918, 584; *Spirochaeta berbera* Kolle and Hetsch, Exper. Bakt. u. Infekt., 6 Aufl., *1*, 1922, 811; *Treponema berberum* Brumpt, Nouveau Traité de Médecine, Paris, *4*, 1922, 496; Bergey et al., Manual, 2nd ed., 1925, 435.) Named for the Berbers, a tribe of Northern Africa.

Morphology: More tenuous than other relapsing fever organisms, 0.2 to 0.3 by 12 to 24 microns.

Cultivation: No record of its cultivation.

Immunology: Antigenically distinct from *Borrelia recurrentis*.

Arthropod vector: Possibly carried by the louse (*Pediculus vestimenti*).

Source: Found in cases of relapsing fever in Algiers, Tunis and Tripoli.

Habitat: Cause of relapsing fever in North Africa. Is virulent for monkeys. Produces non-fatal infections in rats and mice.

7. **Borrelia carteri** (Mackie) Bergey et al. (*Spirochaeta carteri* Mackie, Ann. Trop. Med. and Parasitol., *1*, 1907, 157 and Indian Med. Gazette, *44*, 1908, 370; *Spirillum carteri* Mackie, Lancet, *2*, 1907, 832, according to Ford, Textb. of Bact., 1927, 950; *Spiroschaudinnia carteri* Castellani and Chalmers, Man. Trop. Med., 2nd ed., 1913, 401; *Spironema carteri* Noguchi, Jour. Exp. Med., *27*, 1918, 584; *Treponema carteri* Brumpt, Nouveau Traité de Médecine, Paris, *4*, 1922, 497; Bergey et al., Manual, 2nd ed., 1925, 435.) Named for Carter, who in 1879 described this organism in the blood of patients with Indian relapsing fever.

Morphology: Similar to *Borrelia berbera*.

Cultivation: Not recorded.

Immunology: Probably a distinct species. A succession of distinct serological types occurs with the relapses in a single infection (Cunningham et al., Far Eastern Association of Tropical Medicine, Tokyo, 1925; Indian Journal of Medical

Research, *22*, 1934–1935, 105 and 595; *ibid.*, *24*, 1937, 571 and 581).

Arthropod vector: Carried by either *Pediculus vestimenti* or *Cimex rotundatus* or by both.

Habitat: The cause of Indian relapsing fever. Transmissible to monkeys, rabbits, rats and mice.

8. **Borrelia theileri** (Laveran) Bergey et al. (*Spirochaeta theileri* Laveran, Compt. rend. Acad. Sci., Paris, *136*, 1903, 939; *Spiroschaudinnia theileri* Castellani and Chalmers, Man. Trop. Med., 2nd ed., 1913, 404; *Spironema theileri* Noguchi, Jour. Exp. Med., *27*, 1918, 584; Bergey et al., Manual, 2nd ed., 1925, 435; *Spirillum theileri* and *Spirochaete theileri* Pettit, Contribution à l'Étude des Spirochétidés, Vanves, II, 1928; *Treponema theileri* Noguchi, in Jordan and Falk, Newer Knowledge Bact. and Immun., 1928, 461.) Named for Theiler, who discovered this organism in 1902 in Transvaal, South Africa.

Morphology: 0.25 to 0.3 micron by 20 to 30 microns with pointed ends.

Cultivation: No record.

Immunology: Is distinct from the species infecting man.

Arthropod vector: Transmitted by the tick (*Rhipicephalus decoloratus*).

Source: Blood of cattle.

Habitat: Blood of cattle and other mammals in South Africa.

9. **Borrelia glossinae** (Novy and Knapp) Bergey et al. (*Spirillum glossinae* Novy and Knapp, Jour. Inf. Dis., *3*, 1906, 385; *Spirochaeta glossinae* Castellani and Chalmers, Man. Trop. Med., 1st ed., 1910, 310; *Spiroschaudinnia glossinae* Castellani and Chalmers, *ibid.*, 3rd ed., 1919, 454; *Spironema glossinae* Bergey et al., Manual, 1st ed., 1923, 425; Bergey et al., Manual, 2nd ed., 1925, 435; *Entomospira glossinae* Enderlein, Bakterien-Cyclogenie, 1925, 254; *Treponema glossinae* Ford, Textb. of Bact., 1927, 988.) Named for the genus of insects, *Glossina*.

Morphology: 0.2 by 8.0 microns, occurring singly, sometimes in pairs. Generally 4 spirals. Shorter, narrower and has more turns than has *Borrelia recurrentis*.

Habitat: Found in the stomach contents of the tse-tse fly (*Glossina palpalis*).

10. **Borrelia buccale** (Steinberg) Brumpt. (*Spirochaeta buccalis* Steinberg, 1862, according to Hoffmann and Prowazek, Cent. f. Bakt., I Abt., Orig., *41*, 1906, 819; *Spirochaete cohnii* Winter, Die Pilze, 1879, 61; (?) *Microspira buccalis* Lewis, The Lancet, 1884, quoted from Schroeter, in Cohn, Kryptog. Flora v. Schlesien, *3*, 1, 1889, 169; *Spirochaete buccalis*, quoted from Schroeter, *ibid.*, 168; *Spirillum cohnii* Trevisan, I generi e le specie delle Batteriacee, 1889, 24; *Spirillum buccale* Macé, Traité Pratique de Bact., 4th ed., 1901, 1062; *Spirochaeta inaequalis* Gerber, Cent. f. Bakt., I Abt., Orig., *56*, 1910, 508; *Spirochaeta undulata* Gerber, *idem*; *Treponema buccale* Dobell, Arch. f. Protistenk., *26*, 1912, 117; *Spironema buccale* Gross, Cent. f. Bakt., I Abt., Orig., *65*, 1912, 84; *Spiroschaudinnia buccalis* Castellani and Chalmers, Man. Trop. Med., 3rd ed., 1919, 450; Brumpt, Nouveau Traité de Médecine, Paris, *4*, 1922, 495; *Treponema inaequale* Brumpt, *ibid.*; *Treponema undulatum* Brumpt, *ibid.*, 514.) From Latin *buccalis*, buccal.

Morphology: 0.4 to 0.9 by 7 to 20 microns. The largest of the mouth spirochetes.

Motility: Active, serpentine, rotating and flexuous.

Staining: Stains with aniline dyes and is violet with Giemsa's stain.

Cultivation: Has not been obtained in pure culture and probably does not grow in any medium tried to date.

Habitat: In normal mouths and invades formed lesions of the respiratory mucous membrane.

11. **Borrelia vincentii** (Blanchard) Bergey et al. (*Spirochaeta vincenti* Blanchard, Arch. f. Protistenk., *10*, 1906, 129; *Spirochaeta schaudinni* Prowazek, Arb. kaiserl. Gesundheitsamte, *22*, 1907, 23; *Spirochaete plaut-vincenti* Lehmann and Neumann, Bakt. Diag., 5 Aufl., *2*, 1912, 579; *Spiroschaudinnia vincenti* Castellani and Chalmers, Man. Trop. Med., 2nd ed., 1913, 402; *Spiroschaudinnia schaudinni* Castellani and Chalmers, *idem*; *Spironema vincenti* Park and Williams, Pathogenic Microorganisms, 6th ed., 1917, 506; *Treponema vincenti* Brumpt, Nouveau Traité de Médecine, Paris, *4*, 1922, 514; *Treponema schaudinni* Brumpt, *idem*; Bergey et al., Manual, 2nd ed., 1925, 435.) Named for Vincent, the French bacteriologist.

Morphology: 0.3 by 8 to 12 microns, 3 to 8 irregular shallow spirals. Stains easily with the common aniline dyes and is Gram-negative.

Motility: Has a rapid progressive and vibratory motion.

Cultivation: Can be cultivated under anaerobic conditions. Cultures may show long forms with only a writhing motion.

Not pathogenic for laboratory animals.

Habitat: Found on normal respiratory mucous membrane and is associated with a fusiform bacillus (*Fusobacterium plauti-vincenti*) in Vincent's angina.

12. **Borrelia refringens** (Schaudinn and Hoffmann) Bergey et al. (*Spirochaeta refringens* Schaudinn and Hoffmann, Arbeiten kaiserl. Gesundheitsamte, *22*, 1905, 528; *Spirochaeta refringens* Hoffmann and Prowazek, Cent. f. Bakt., I Abt., Orig., *41*, 1906, 742; *Spironema refringens* Gross, Arch. f. Protistenk., *24*, 1912, 115; *Spiroschaudinnia refringens* Castellani and Chalmers, Man. Trop. Med., 3rd ed., 1919, 459; *Treponema refringens* Castellani and Chalmers, *ibid.*, 461; Bergey et al., Manual, 2nd ed., 1925, 436.) From Latin, refractive.

Morphology: 0.5 to 0.75 by 6 to 20 microns. Spirals are coarse and shallow. Spirals are generally smoothly rounded and regular, tapering towards the end into a fine projection. Stains easily by common dyes. In stained specimens the spirals appear irregular.

Motility: Active serpentine and rotating motion with marked flexion.

Cultivation: Uncertain.

Pathogenicity: None.

Source: Found with *Treponema pallidum* in some cases of syphilis as originally described by Schaudinn.

Habitat: Genital mucous membranes and necrotic lesions of the genitalia of man.

13. **Borrelia hyos** (King and Drake) Bergey et al. (Hog cholera virus, King and Baeslack, Jour. Inf. Dis., *12*, 1913, 39; *Spirochaeta suis* King, Baeslack and Hoffmann, Jour. Inf. Dis., *12*, 1913, 235; not *Spirochaeta suis* Bosanquet, Spirochetes, Saunders, 1911; *Spirochaeta hyos* King and Drake, Jour. Inf. Dis., *16*, 1915, 54; *Spironema hyos* Bergey et al., Manual, 1st ed., 1923, 426; Bergey et al., Manual, 2nd ed., 1925, 436; *Spironema suis* Ford, Textb. of Bact., 1927, 959.) From Greek, hog.

Morphology: 1 micron by 5 to 7 microns. Distinctly shorter and thicker than other members of the genus.

Motility: Active spinning motion, spirals fixed.

Cultivation: Grows under anaerobic conditions in the presence of tissue.

Habitat: Found in the blood, intestinal ulcers and other lesions of hogs suffering from hog cholera.

14. **Borrelia hermsi** (Davis) Steinhaus. (*Spirochaeta hermsi* Davis, Amer. Assoc. Adv. Sci., Pub. No. 18, 1942, 46; Steinhaus, Insect Microbiology, 1946, 453.)

Investigations by Davis (*loc. cit.*) indicate that each species of *Ornithodoros* that is a relapsing fever vector carries a spirochete that is tick-host specific and that this host-specific relationship offers a more accurate approach to the differentiation of relapsing fever spirochetes

than any of the several criteria previously used.

This was shown to be the case for *Borrelia hermsi* and *Borrelia parkeri*. For this reason no attempt is made to describe the morphology and other characters of the relapsing fever spirochetes of North and South America.

Borrelia hermsi is transmitted by *Ornithodoros hermsi*.

A cause of relapsing fever in the Western part of the U. S. A.

15. **Borrelia parkeri** (Davis) Steinhaus. (*Spirochaeta parkeri* Davis, *loc. cit.*; Steinhaus, *loc. cit.*)

Transmitted by *Ornithnodoros parkeri*.

A cause of relapsing fever in the Western part of the U. S. A.

16. **Borrelia turicatae** (Brumpt) Steinhaus. (*Spirochaeta turicatae* Brumpt, Comp. rend. Soc. Biol., Paris, *113*, 1933, 1369; Steinhaus, *loc. cit.*)

Transmitted by *Ornithodoros turicata*.

A cause of relapsing fever in Mexico, Texas and nearby areas.

17. **Borrelia venezuelensis** Brumpt. (*Treponema venezuelensis* Brumpt, Nouveau Traité de Médecine, Paris, *4*, 1921, 492; Brumpt, *ibid.*, 495; *Spirochaeta venezuelensis* Pettit, Contributions à l'Étude des Spirochétidés, Vanves, *2*,1928, 295.)

Transmitted by *Ornithodoros rudis* (*O. venezuelensis*).

A cause of South American relapsing fever.

Brumpt (Précis de Parasitologie, 3rd ed., Paris, 1936) regards this species as identical with *Borrelia neotropicalis* (Bates, Dunn and St. John) Steinhaus. (*Treponema neotropicalis* Bates, Dunn and St. John, Amer. Jour. Trop. Med., *1*, 1921, 183; *Spirochaeta neotropicalis* St. John and Bates, Amer. Jour. Trop. Med., *2*, 1922, 251; Steinhaus, *loc. cit.*) Transmitted by *Ornithodoros venezuelensis*. A cause of relapsing fever in **Panama.**

Appendix: Many of the species included in this appendix are so inadequately described that it is not certain that they belong in this group.

Borrelia phagedenis (Noguchi) Bergey et al. (*Spirochaeta phagedenis* Noguchi, Jour. Exp. Med., *16*, 1912, 261; *Spiroschaudinnia phagedenis* Castellani and Chalmers, Man. Trop. Med., 2nd ed., 1913, 403; *Treponema phagedenis* Brumpt, Nouveau Traité de Médecine, Paris, *4*, 1922, 511; *Spironema phagedenis* Bergey et al., Manual, 1st ed., 1923, 426; Bergey et al., Manual, 2nd ed., 1925, 435.) From phagedenous ulcer.

Heliconema pyrphoron Scholer. (Cent. f. Bakt., I Abt., Orig., *138*, 1937, 342.) From human blood. Pathogenic.

Heliconema vincenti Sanarelli. (Ann. Inst. Past., *41*, 1927, 701.) From the intestine of a guinea pig. Shows stages between spirochetes and fusiform bacilli. (See Hindle, Med. Res. Council Syst. of Bact., *8*, 1931, 130.)

Microspironema merlangi Duboscq and Lebailly. (Compt. rend. Acad. Sci. Paris, *154*, 1912, 662.) From the whiting, *Merlangus merlangus*. May be a synonym of *Spirochaeta gadi*.

Spirillum gondii Nicolle. (Nicolle, Compt. rend. Soc. Biol., Paris, *63*, 1907, 213; *Spirochaeta gondi* Zuelzer, 1925, in Prowazek, Handb. d. path. Protoz., *3*, 1931, 1680.) Found in the blood of a rodent, *Ctenodactylus gondi*. Not pathogenic. Associated with a piroplasma. Probably not a spirochete.

Spirillum latapiei Laveran. (Laveran, Bull. Soc. Path. Exot., *1*, 1908, 148; *Spirochaeta latapici* Zuelzer, 1925, in Prowazek, Handb. d. path. Protoz., *3*, 1931, 1683; *Spironema latapici* (sic) Ford, Textb. of Bact., 1927, 964.) From the blood of a shark.

Spirillum pitheci Thiroux and Dufougeré. (Thiroux and Dufourgeré, Compt. rend. Acad. Sci. Paris, *150*, 1910, 132; *Spirochaeta pitheci* Zuelzer, 1925, in Prowazek, Handb. d. path. Protoz., *3*, 1931, 1676; *Spironema pitheci* Ford,

Textb. of Bact., 1927, 961.) From the blood of an African monkey, *Cercopithecus patas*. Pathogenic for monkeys, rats and field mice. Closely related to *Borrelia duttonii*.

Spirochaeta aboriginalis Cleland. (Cleland, Jour. Trop. Med., *12*, 1909, 143; *Spiroschaudinnia aboriginalis* Castellani and Chalmers, Man. Trop. Med., 2nd ed., 1913, 402; *Treponema aboriginalis* Brumpt, Nouveau Traité de Médecine, Paris, *4*, 1922, 496.) Found in cases of granuloma inguinale in West Australia. Probably saprophytic.

Spirochaeta acuminata Castellani. (Castellani, Brit. Med. Jour., *2*, 1905, 1330; *Spirochaeta tenuis acuminata* Castellani, *idem* and/or Arch. f. Schiffs- u. Tropenhyg., *12*, 1908, 311; *Spiroschaudinnia acuminata* Castellani and Chalmers, Man. Trop. Med., 3rd ed., 1919, 449; *Treponema acuminatum* Brumpt, Nouveau Traité de Médecine, Paris, *4*, 1922, 496.) From ulcerated lesions of yaws.

Spirochaeta acuta Kritchewski and Séguin. (Rev. de Stomatol., *22*, 1920, 613.) From the oral cavity.

Spirochaeta aeglefini Henry. (Jour. Path. and Bact., *18*, 1913, 222.) From haddock.

Spirochaeta aegyptica Gonder. (Gonder, in Prowazek, Handb. d. path. Protoz., *6*, 1914, 671; *Spironema aegyptica* Noguchi, Jour. Exp. Med., *27*, 1918, 584; *Treponema egypticum* Brumpt, Nouveau Traité de Médecine, Paris, *4*, 1922, 500; *Borrelia aegypticum* Steinhaus, Insect Microbiology, 1946, 452.) Observed in cases of relapsing fever in Sudan. Probably a synonym of *Borrelia recurrentis*.

Spirochaeta ambigua Séguin and Vinzent. (Séguin and Vinzent, Compt. rend. Soc. Biol., Paris, *121*, 1936, 408; *Treponema ambigua* Prévot, Man. Class. et Determ. d. Bactéries Anaérobies, Paris, 1940, 208.) From the oral cavity and the lungs. Pathogenic. Strict anaerobe.

Spirochaeta amphibiae Yakimoff and Miller. (Bull. Soc. Path. Exot., *18*, 1925, 306.) From the intestines of frogs, *Rana temporaria*.

Spirochaeta argentinensis Kuhn and Steiner. (Kuhn and Steiner, Med. Klin., *13*, 1917, 1007; *Spirochaeta polysclerotica* Arzt and Kerl, according to Pettit, Contribution à l'Étude des Spirochétidés, Vanves, II, 1928, 134; *Treponema* (?) *argentinensis* Noguchi, in Jordan and Falk, Newer Knowledge Bact. and Immun., 1928, 478.) From the livers of guinea pigs and rabbits inoculated with blood from patients having multiple sclerosis. Pathogenic for man, monkeys, dogs, rabbits and guinea pigs. Named for the Latin name of the town of Strasbourg (*Argentoratum*).

Spirochaeta balanitidis Hoffmann and Prowazek. (Hoffmann and Prowazek, Cent. f. Bakt., I Abt., Orig., *41*, 1906, 741; *Spiroschaudinnia balanitidis* Castellani and Chalmers, Man. Trop. Med., 2nd ed., 1913, 404; *Spironema balanitidis* Park and Williams, Pathogenic Microorganisms, 6th ed., 1917, 505; *Treponema balanitidis* Brumpt, Nouveau Traité de Médecine, Paris, *4*, 1922, 496.) From a case of balanitis.

Spirochaeta bovis-caffris Nuttall. (Nuttall, Parasitology, *3*, 1910, 108; *Spironema bovis-caffris* Ford, Textb. of Bact., 1927, 960.) From the blood of a buffalo.

Spirochaeta bronchialis Castellani. (Castellani, Ceylon Medical Reports, 1907; *Spiroschaudinnia bronchialis* Castellani and Chalmers, Man. Trop. Med., 2nd ed., 1913, 402; *Treponema bronchiale* Brumpt, Nouveau Traité de Médecine, Paris, *4*, 1922, 496.) Found in cases of bronchitis in Ceylon. A mixture of several species of mouth spirochaetes is apparently described under this designation.

Spirochaeta bucco-pharyngei Macfie. (Macfie, Ann. Trop. Med. and Parasitol., *10*, 1916, 329; *Treponema bucco-pharyngei* Brumpt, Nouveau Traité de Médecine, Paris, *4*, 1922, 497.) From the throat of a native of the Gold Coast. May be identical with *Spirochaeta dentium* or *S. buccalis*.

Spirochaeta bufonis Dobell. (Dobell, Quart. Jour. Microsc. Sci., *52*, 1908, 121; *Spiroschaudinnia bufonis* Castellani and Chalmers, Man. Trop. Med., 3rd ed., 1919, 454; *Spironema bufonis* Ford, Textb. of Bact., 1927, 986; *Treponema bufonis* Ford, *ibid.*) From the intestines of a toad, *Bufo vulgaris*.

Spirochaeta caesirae retortiformis Hellmann. (Arch. f. Protistenk., *29*, 1913, 22.) From the urinary sac of a tunicate, *Caesira retortiformis*.

Spirochaeta caesirae septentrionalis Hellmann. (Arch. f. Protistenk., *29*, 1913, 22.) From the urinary sac of a tunicate, *Caesira septentrionalis*.

Spirochaeta canina Bosselut. (Bull. Soc. Path. Exot., *18*, 1925, 702.) From the blood of a dog.

Spirochaeta canis Macfie. (Ann. Trop. Med. and Parasitol., *10*, 1916, 305.) From dog feces.

Spirochaeta cobayae Knowles and Basu (Knowles and Basu, Indian Jour. Med. Res., *22*, 1935, 449; *Treponema cobayae* Topley and Wilson, Princip. Bact. and Immun., 2nd ed., 1936, 725; *Borrelia cobayae* Steinhaus, Insect Microbiology, 1946, 454.) From the blood of guinea pigs. Blood parasite belonging to the relapsing fever group. Pathogenic for guinea pigs, rabbits and white rats.

Spirochaeta comandoni Séguin and Vinzent. (Séguin and Vinzent, Compt. rend. Soc. Biol., Paris, *121*, 1936, 408; *Treponema comandoni* Prévot, Man. Class. et Determ. d. Bactéries Anaérobies, Paris, 1940, 208.) From the oral cavity. Rather common. Non-pathogenic. Strict anaerobe.

Spirochaeta crocidurae Leger. (Leger, Bull. Soc. Path. Exot., *10*, 1917, 280; *Treponema crocidurae* McFarland, Pathogenic Bacteria and Protozoa, 2nd ed., 1933, 136.) From a shrew-mouse, *Crocidura stampflii*, in Senegal. Transmitted by *Ornithodoros erraticus*.

Spirochaeta ctenocephali Patton. (Patton, Ann. Trop. Med. and Parasitol., *6*, 1912, 357; *Treponema ctenocephali* Ford, Textb. of Bact., 1927, 989.) Parasitic in the digestive tract of the larvae of the Indian cat-flea, *Ctenocephalus felis*.

Spirochaeta cubensis Hoffman. (Sanidad y Beneficienca Boletin oficial, Havana, *28*, 1923, 76.) From the feces of *Hyla septentrionalis*.

Spirochaeta culicis Jaffé. (Jaffé, Arch. f. Protistenk., *9*, 1907, 100; *Spironema culicis* Gross, Cent. f. Bakt., I Abt., Orig., *65*, 1912, 87; *Entomospira culicis* Enderlein, Sitzungsber. Ges. Naturf. Freunde, Berlin, 1917, 313; *Spiroschaudinnia culicis* Castellani and Chalmers, Man. Trop. Med., 3rd ed., 1919, 454; *Spirillum culicis* Pringault, Compt. rend. Soc. Biol., Paris, *84*, 1921, 209; *Treponema culicis* Ford, Textb. of Bact., 1927, 989.) Found in the intestines and Malpighian tubules of mosquito larvae, *Culex sp.*

Spirochaeta didelphis Vianna, de Figueiredo and Cruz. (Brasil-Medico, *26*, 1912, 912.) From the blood of an opossum, *Didelphis aurita*.

Spirochaeta equi (Novy and Knapp) Castellani and Chalmers. (*Spirillum equi* Novy and Knapp, Jour. Inf. Dis., *3*, 9106, 294; Castellani and Chalmers, Man. Trop. Med., 1st ed., 1910, 309; *Spiroschaudinnia equi* Castellani and Chalmers, Man. Trop. Med., 2nd ed., 1913, 404; *Spironema equi* Noguchi, Jour. Exp. Med., *27*, 1918, 584; *Treponema equi* Noguchi, in Jordan and Falk, Newer Knowledge Bact. and Immun., 1928, 461.) From the blood of a horse. May be identical with *Borrelia theileri*.

Spirochaeta equina. (Dodd ?, Jour. Comp. Pathol. and Therap., *19*, 1906, 318; quoted from Pettit, Contribution à l'Étude des Spirochétidés, Vanves, II, 1928, 111.)

Spirochaeta eurygyrata Werner. (Werner, Cent. f. Bakt., I Abt., Orig., *52*, 1909, 241; *Spironema eurgyratum* (sic) Noguchi, Jour. Exp. Med., *27*, 1918, 584; *Spiroschaudinnia eurygyrata* Castellani and Chalmers, Man. Trop. Med., 3rd ed., 1919, 451; *Spirillum eurygyrata* Castellani and Chalmers, *ibid.*; *Borrelia eury-*

gyrata Brumpt, Nouveau Traité de Médecine, Paris, *4*, 1922, 495; *Treponema eurygyratum* Brumpt, *ibid.*, 50.) From the intestinal contents of man.

Spirochaeta exanthematotyphi Futaki. (Futaki, Brit. Med. Jour., Oct. 13, 1917; *Treponema exanthematotyphi* Savini, Compt. rend. Soc. Biol., Paris, *88*, 1923, 958.) Found in the kidneys and urine of cases of exanthematous typhus. Non-pathogenic.

Spirochaeta febris Chester. (Afanassiew, Cent. f. Bakt., I Abt., *25*, 1899, 405; Chester, Man. Determ. Bact., 1901, 347.) From a case of recurrent fever.

Spirochaeta gadi Neumann. (Neumann, Ztschr. f. Hyg., *64*, 1909, 79; *Microspironema gadi* Duboscq and Lebailly, Compt. rend. Acad. Sci. Paris, *154*, 1912, 662; *Treponema gadi* Duboscq and Lebailly, Arch. zool. expér. et génér., *10*, 1912, 331; *Spironema gadi* Ford, Textb. of Bact., 1927, 964.) From the blood of a sea fish, *Gadus minutus*.

Spirochaeta gallica Couvy and Dujarric de la Rivière. (Couvy and Dujarric de la Rivière, Compt. rend. Soc. Biol., Paris, *81*, 1918, 22; *Treponema gallicum* Brumpt, Nouveau Traité de Médecine, Paris, *4*, 1922, 500.) From the blood of trench fever patients.

Spirochaeta gangraenae carcinomatosae Hoffmann. (Berl. klin. Wochnschr., *42*, 1905, 880.) From malignant tumors.

Spirochaeta gangraenosa nosocomialis Róna. (Róna, Verhandl. d. deutsch. dermat. Gesellsch., *9*, 1907, 471; *Treponema gangraenosa nosocomialis* Noguchi, Jour. Exp. Med., *16*, 1912, 261.) From ulcers of the genital region.

Spirochaeta haemophilus Trosier and Sifferlen. (Ann. Inst. Past., *58*, 1937, 233.) From a child with intestinal trouble and continuous fever.

Spirochaeta hispanica de Buen. (De Buen, Ann. Parasitol., *4*, 1926, 185; *Treponema hispanicum* Noguchi, in Jordan and Falk, Newer Knowledge Bact. and Immun., 1928, 481; *Spirochaeta marocanum* Nicolle and Anderson, Compt. rend. Acad. Sci. Paris, *187*, 1928, 747; *Spirochaeta hispanicum* var. *marocanum* Nicolle, Anderson and Colas-Belcour, Arch. Inst. Past. Tunis, *18*, 1929, 343; *Treponema hispanicum* var. *marocanum* Gay et al., Agents of Disease and Host Resistance, 1935, 1074; *Borrelia hispanicum* Steinhaus, Insect Microbiology, 1946, 453.) The cause of Spanish and Moroccan relapsing fever. Transmitted by *Ornithodoros marocanus*. Not agglutinated by serum of *Borrelia recurrentis*. Pathogenic for man and laboratory animals.

Spirochaeta intestinalis Macfie and Carter. (Macfie and Carter, Ann. Trop. Med. and Parasitol., *11*, 1917, 79; *Treponema intestinale* Brumpt, Nouveau Traité de Médecine, Paris, *4*, 1922, 505.) From human feces.

Spirochaeta jonesii Dutton, Todd and Tobey. (Dutton, Todd and Tobey, Jour. Med. Res., *15* (N.S. *10*), 1906, 491; *Spironema jonesii* Ford, Textb. of Bact., 1927, 964.) From the blood of an African mudfish, *Clarias angolensis*.

Spirochaeta lagopodis Fantham. (Fantham, Proc. Zool. Society, London, 1910, 692; *Spironema lagopodis* Noguchi, according to Pettit, *loc. cit.*) From the blood of the grouse, *Lagopus scoticus*.

Spirochaeta leucotermitis Hollande. (Arch. zool. expér. et gén., *61*, 1922, 23.) From an insect, *Leucotermes lucifugus*.

Spirochaeta lovati Fantham. (Proc. Zool. Society, London, 1910.) From the intestinal contents of the grouse, *Lagopus scoticus*.

Spirochaeta lowenthali Besson. (Besson, p. 736, according to Ford, Textb. of Bact., 1927, 1001.) From malignant tumors.

Spirochaeta lutrae Prowazek. (Prowazek, Arb. kaiserl. Gesundheitsamte, *26*, 1907, 31; *Spiroschaudinnia lutrae* Castellani and Chalmers, Man. Trop. Med., 2nd ed., 1913, 404; *Spironema lutrae* Ford, Textb. of Bact., 1927, 961.) From the blood of an otter, *Lutra sp.*

Spirochaeta lymphaticus Proescher and White. (Proescher and White, Jour. Amer. Med. Assoc., *49*, 1907, 1988;

Treponema lymphaticum Brumpt, Nouveau Traité de Médecine, Paris, *4*, 1922, 506.) From cases of lymphatic leukemia. Pathogenic for guinea pigs, rats and monkeys.

Spirochaeta macaci Castellani and Chalmers. (Castellani and Chalmers, 1908, see Castellani and Chalmers, Man. Trop. Med., 1st ed., 1910, 310; *Spiroschaudinnia macaci* Castellani and Chalmers, Man. Trop. Med., 2nd ed., 1913, 403; *Spironema macaci* Ford, Textb. of Bact., 1927, 960.) From monkeys in Ceylon. Closely related to or possibly identical with *Borrelia carteri*.

Spirochaeta marmotae Carpano. (Ann. d'Igien. sper., *23*, 1913, 215.) From a rodent, *Arctomys marmota*.

Spirochaeta melanogenes canis Lukeš. (Deutsch. Tierärztl. Wochnschr., 1923, 137; see Ann. Inst. Past., *38*, 1924, 523.) From the intestines of a dog. The cause of a dog plague.

Spirochaeta melophagi Porter. (Quart. Jour. Microsc. Sci., London, *55*, 1910, 189.) From the intestine, ovaries, and pupa of *Melophagus ovinus*.

Spirochaeta metritis de Andrade. (Compt. rend. Soc. Biol., Paris, *86*, 1922, 1048.) From a uterine excretion.

Spirochaeta microgyrata gaylordi Calkins. (Calkins, Jour. Inf. Dis., *4*, 1907, 173; *Spirochaeta microgyrata* var. *gaylordi* Calkins, *ibid.*, 171; *Spironema microgyrata* var. *gaylordi* Ford, Textb. of Bact., 1927, 1001.) From breast tumors of mice.

Spirochaeta naganophila Savini. (Compt. rend. Soc. Biol., Paris, *88*, 1923, 956.) From the blood of mice. No description given.

Spirochaeta noelleri Zuelzer. (1925, in Prowazek, Handb. d. path. Protoz., *3*, 1931, 1684.) From the intestine of the larvae of *Simulium noelleri*.

Spirochaeta noguchii Strong. (Strong, United Fruit Co. Med. Dept. 14th Ann. Rept., 1925; *Treponema noguchii* Noguchi, in Jordan and Falk, Newer Knowledge Bact. and Immun., 1928, 483.) From a type of skin ulcer in South America.

Spirochaeta normandi Nicolle, Anderson and Colas-Belcour. (Compt. rend. Acad. Sci. Paris, *185*, 1927, 334.) From *Ornithodoros normandi*, the natural agent of transmission. Pathogenic for white mice.

Spirochaeta normandi var. *carthaginensis*. (Quoted from Hindle, Med. Res. Council Syst. of Bact., *8*, 1931, 169.) From ticks in Tunis.

Spirochaeta nosocomialis Hoffmann and Gonder. (Hoffmann and Gonder, 1914, according to Brumpt, Nouveau Traité de Médecine, Paris, *4*, 1922, 508; *Treponema nosocomiale* Brumpt, *ibid.*) Probably a synonym of *Borrelia vincentii*.

Spirochaeta obtusa Castellani. (Castellani, Brit. Med. Jour., *2*, 1905, 1330; *Spirochaeta tenuis obtusa* Castellani, 1908, according to Ford, Textb. of Bact., 1927, 973; *Spiroschaudinnia obtusa* Castellani, Arch. f. Schiffs- u. Tropenhyg., *12*, 1908, 311 (see Castellani and Chalmers, Man.. Trop. Med., 3rd ed., 1919 449); *Treponema obtusum* Brumpt, Nouveau Traité de Médecine, Paris, *4*, 1922, 508; *Treponema tenue obtusum* Brumpt, *ibid.*) From ulcerated lesions of yaws.

Spirochaeta ovis (Novy and Knapp) Bergey et al. (*Spirillum ovis* Novy and Knapp, Jour. Inf. Dis., *3*, 1906, 294; *Spirochaeta ovina* Blanchard, Semaine Médicale, *26*, 1906, 1; *Spiroschaudinnia ovina* Castellani and Chalmers, Man. Trop. Med., 2nd ed., 1913, 404; *Spironema ovis* Ford, Textb. of Bact., 1927, 960; *Treponema ovis* Noguchi, in Jordan and Falk, Newer Knowledge Bact. and Immun., 1928, 461; *Treponema ovinum* Noguchi, *ibid.*, 480; Bergey et al., Manual, 5th ed., 1939, 960.) From the blood of sheep. May be identical with *Borrelia theileri*.

Spirochaeta pelamidis Neumann. (Neumann, Ztschr. f. Hyg., *64*, 1909, 80; *Spironema pelamidis* Ford, Textb. of Bact., 1927, 964.) From the blood of a fish, *Pelamys sarda*. Resembles *Spirochaeta gadi*.

Spirochaeta perforans Cavalié and Mandoul. (Compt. rend. Soc. Biol., Paris,

85, 1921, 1068.) From cases of pyorrhea alveolaris. Associated with fusiform bacilli. Probably synonymous with *Borrelia vincentii*.

Spirochaeta periplanetae Laveran and Franchini. (Bull. Soc. Path. Exot., *13*, 1920, 332.) From the digestive tract of the cockroach, *Periplaneta orientalis*.

Spirochaeta persica Dschunkowsky. (Dschunkowsky, Deutsch. med. Wochnschr., *39*, 1913, 419; *Treponema persicum* Brumpt, Nouveau Traité de Médecine, Paris, *4*, 1922, 509; *Borrelia persica* Steinhaus, Insect Microbiology, 1946, 452.) From a case of relapsing fever (Mianeh fever) in Persia. Transmitted by *Ornithodoros tholozani* and *O. latiorensis*. Serum not agglutinated by *Borrelia recurrentis*. Disease in man fairly severe and in gerbilles and monkeys very mild.

Spirochaeta pollachii Henry. (*Spirochaeta gadi pollachii* Henry, Jour. Path. and Bact., *14*, 1910, 463; Henry, *ibid.*, *17*, 1912, 160; *Treponema fallax* Duboscq and Lebailly, Arch. Zool. Expér. et Gén., *10*, 1912, 331; *Spirochaeta fallax* Zuelzer, 1925, in Prowazek, Handb. d. path. Protoz., *3*, 1931, 1671; *Spironema pollachii* Ford, Textb. of Bact., 1927, 965.) From the blood of the pollack, *Gadus pollachius*.

Spirochaeta pseudobuccalis Zuelzer. (Cent. f. Bakt., I Abt., Orig., *85*, 1921, *154.)

Spirochaeta pseudorecurrentis Zuelzer. (Cent. f. Bakt., I Abt., Orig., *85*, 1921, *154.)

Spirochaeta pyorrhoeica Kolle. (Med. Klin., *13*, 1917, 59.) Commonly found in pus from pyorrhea alveolaris.

Spirochaeta raillieti Mathis and Leger. (Compt. rend. Soc. Biol., Paris, *70*, 1911, 212.) From the blood of a rabbit. Not pathogenic.

Spirochaeta ranarum Yakimoff and Miller. (Bull. Soc. Path. Exot., *18*, 1925, 306.) From the intestines of frogs, *Rana temporaria*.

Spirochaeta recta Gerber. (Gerber, Cent. f. Bakt., I Abt., Orig., *56*, 1910, 513; *Treponema rectum* Brumpt, Nouveau Traité de Médecine, Paris, *4*, 1922, 511.) May be a synonym of *Borrelia vincentii*.

Spirochaeta regaudi Ball and Roquet. (Ball and Roquet, 1911, according to Pettit, Contribution à l'Étude des Spirochétidés, Vanves, II, 1928; *Spirella regaudi* Ball and Roquet, 1911, according to Brumpt, Nouveau Traité de Médecine, Paris, *4*, 1922, 517; also see Edkins, Parasitology, *15*, 1923, 296.) From the stomachs of cats and dogs. Possibly belongs among the spirilla (Noguchi); is in the same group as *Cristispirella* and *Heliconema*.

Spirochaeta sinensis Pons. (Compt. rend. Soc. Biol., Paris, *89*, 1923, 1028.) From the blood of a fever patient in China. Pathogenic for rabbits and monkeys.

Spirochaeta sogdianum Nicolle and Anderson. (Nicolle and Anderson, Compt. rend. Acad. Sci. Paris, *187*, 1928, 746; *Borrelia sogdianum* Steinhaus, Insect Microbiology, 1946, 453.) Not pathogenic for guinea pigs or fowls. Probably synonymous with *Borrelia recurrentis*.

Spirochaeta sporogenes psoriasis Rasck. (Individual publications, Christiania, 1920–1921, 4.)

Spirochaeta sporogona rheumatismi Rasck. (Individual publications, Christiania, 1920–1921, 4.) From the blood in cases of acute arthritis.

Spirochaeta staphylina Ghidini and Archetti. (Riv. Biol. Coloniale, *2*, 1939, 131.) From the intestine of a termite, *Reticulitermes lucifugus*, Italy.

Spirochaeta stenogyrata Werner., (Werner, Cent. f. Bakt., I Abt., Orig., *52*, 1909, 241; *Treponema stenogyratum* Brumpt, Nouveau Traité de Médecine, Paris, *4*, 1922, 514.) From human feces.

Spirochaeta suilla Dodd. (Jour. Compt. Path. and Therap., *19*, 1906, 216.) From cutaneous lesions of pigs. Pathogenic for pigs.

Spirochaeta temporariae Yakimoff and Miller. (Bull. Soc. Path. Exot., *18*,

1925, 306.) From the intestines of frogs, *Rana temporaria*.

Spirochaeta tenuis Gerber. (Gerber, Cent. f. Bakt., I Abt., Orig., *56*, 1910, 508; *Treponema tenue* Brumpt, Nouveau Traité de Médecine, Paris, *4*, 1922, 514.) May be identical with *Spirochaeta dentium* or with *Borrelia vincentii*.

Spirochaeta termitis (Leidy) Dobell. (*Vibrio termitis* Leidy, Jour. Acad. Nat. Sci., Phila., 2nd Ser., *8*, 1881, 441; *Spirochaeta minei* Prowazek, Arch. f. Schiffs- u. Tropenhyg., *14*, 1910, 297; Dobell, Spolia ceylanica, *3*, 1910, 78; *Treponema minei* Dobell, *ibid.; ? Spirochaete grassii* Döflein, Prob. der Protistenk., *2*, 1911, 17; *Spirochaeta grassii* Döflein, Die Natur der Spirochäten, Jena, 1911; *Treponema termitis* Dobell, Arch. f. Protistenk., *26*, 1912, 117; *Entomospira grassii* Enderlein, Sitzungsber. Ges. Naturf. Freunde, Berlin, 1917, 313; *Cristispira termitis* Hollande, Arch. Zool. Expér. et Gén., *61*, 1923, N. and R., 25; *Treponema grassi* Ford, Textb. of Bact., 1927, 988.) From the intestines of *Termes lucifugus* and *Calotermes spp.*

Spirochaeta tropidonoti Dobell. (Dobell, Spolia ceylanica, *7*, 1911, 65; *Spironema tropidonoti* Ford, Textb. of Bact., 1927, 962.) Isolated once from the blood of a snake, *Tropidonotus stolatus*, in Ceylon.

Spirochaeta urethrae Macfie. (Macfie, Ann. Trop. Med. and Parasitol., *10*, 1916, 305; *Spiroschaudinnia urethrae* Castellani and Chalmers, Man. Trop. Med., 3rd ed., 1919, 451; *Treponema urethrae* Brumpt, Nouveau Traité de Médecine, Paris, *4*, 1922, 514.) From the urine of Gold Coast natives. Causes acute arthritis.

Spirochaeta usbekistanica Pickoul. (Russ. Jour. Trop. Med., *6*, 1928, 612.) From cases of relapsing fever in Bokhara.

Spirochaeta vespertilionis (Novy and Knapp) Castellani and Chalmers. (*Spirillum vespertilionis* Novy and Knapp, Jour. Inf. Dis., *3*, 1906, 294; Castellani and Chalmers, Man. Trop. Med., 1st ed., 1910, 309; *Spiroschaudinnia vespertilionis* Castellani and Chalmers, Man. Trop. Med., 3rd ed., 1919, 454; *Spironema vespertilionis* Ford, Textb. of Bact., 1927, 961.) From the blood of a bat, *Vespertilio kuhlii*.

Spirochaeta vincenti var. *bronchialis* Delamare. (Compt. rend. Soc. Biol., Paris, *90*, 1924, 611.)

Spirochaeta zlatogorovi Yakimoff. (Bull. Soc. Path. Exot., *14*, 1921, 532.) From feces.

Spirochaete exanthematica Lewascheff. (Cent. f. Bakt., I Abt., *18*, 1895, 133.) From the blood in cases of typhus fever.

Spirochaete forans Reiter. (Reiter, Deutsch. med. Wochnschr., No. 50, 1916, 10; see Cent. f. Bakt., I Abt., Orig., *79*, 1917, 176; *Treponema forans* Brumpt, Nouveau Traité de Médecine, Paris, *4*, 1922, 500; *Spirochaeta forans* Pettit, Contribution à l'Étude des Spirochétidés, Vanves, II, 1928, 164.) From the blood in a case of articular rheumatism. Not pathogenic for guinea pigs or mice.

Spirochaete gracilis Veszpremi. (Veszpremi, Cent. f. Bakt., I Abt., Orig., *44*, 1907, 332; not *Spirochaeta gracilis* Levaditi and Stanesco, Compt. rend. Soc. Biol., Paris, *67*, 1909, 188 (*Treponema levaditii* Brumpt, Nouveau Traité de Médecine, Paris, *4*, 1922, 501; *Treponema gracile* Brumpt, *idem*); *Treponema gracile* Ford, Textb. of Bact., 1927, 978.) From a gangrenous phlegmon of the mouth. Found in association with fusiform bacilli and therefore may be identical with *Borrelia vincentii* or *Spirochaeta dentium* or *Treponema macrodentium*.

Spirochaete repacis. (Quoted from Lehmann and Neumann, Bakt. Diag., 6 Aufl., *2*, 1920, 809.) From the oral cavity.

Spironema caviae Ford. (Spirochaete (?), Macfie, Ann. Trop. Med. and Parasitol., *8*, 1914, 447; Ford, Textb. of Bact., 1927, 961.) From the blood of a guinea pig at Lagos.

Spironema vesperuginis (Gonder) Ford. (*Spirochaeta vesperuginis* Gonder, Arb. kais. Gesundheitsamte, *27*, 1908, 406; Ford, Textb. of Bact., 1927, 961.) From the blood of a bat, *Vesperugo kuhlii*.

Spiroschaudinnia caviae Sangiorgi.

(Sangiorgi, Pathologica Rivista, *5*, 1913, 428; *Spirochaeta caviae* Hindle, Med. Res. Council Syst. of Bact., *8*, 1931, 174.) From the blood of a guinea pig.

Spiroschaudinnia mitis Castellani and Chalmers. (Castellani and Chalmers, Man. Trop. Med., 3rd ed., 1919, 451; *Treponema mite* Brumpt, Nouveau Traité de Médecine, Paris, *4*, 1922, 506.) From urine in mild cases of camp jaundice. Probably not pathogenic.

Treponema lineola (Donné) Brumpt. (*Vibrio lineola* Donné, Recherches Microsc. Nature d. Mucus des Organs Genitourinaires, Paris, 1837; Brumpt, Nouveau Traité de Médecine, Paris, *4*, 1922, 505.) From secretions of the genitalia.

Genus II. Treponema *Schaudinn.*

(*Spironema* Vuillemin, Compt. rend. Acad. Sci. Paris, *140*, 1905, 1567; not *Spironema* Bergey et al., Manual, 1st ed., 1923, 424; Schaudinn, Deutsche med. Wochnschr., *31*, 1905, 1728; *Microspironema* Stiles and Pfender, Amer. Med., *10*, 1905, 936.)

Length 3 to 18 microns. Longer forms due to incomplete division. Protoplasm in acute, regular or irregular spirals. Terminal filament may be present. Some species stain only with Giemsa's stain. Weakly refractive by dark field illumination in living preparations. Cultivated under strictly anaerobic conditions. Pathogenic and parasitic for man and animals. Generally produce local lesions in tissues.

The type species is *Treponema pallidum* (Schaudinn and Hoffmann) Schaudinn.

1. **Treponema pallidum** (Schaudinn and Hoffmann) Schaudinn. (*Spirochaete pallida* Schaudinn and Hoffmann, Arb. kaiserl. Gesundheitsamte, *22*, 1905, 528; Schaudinn, Deutsche med. Wochnschr., *31*, 1905, 1728; *Spironema pallidum* Vuillemin, Compt. rend. Acad. Sci. Paris, *140*, 1905, 1567; *Microspironema pallidum* Stiles and Pfender, Amer. Med., *10*, 1905, 936; *Trypanosoma luis* Krzystalowicz and Siedlecki, 1905, see abst. in Bull. Inst. Past., *4*, 1906, 204; *Spirochaeta pallida* Hoffmann and Prowazek, Cent. f. Bakt., I Abt., Orig., *41*, 1906, 741.) From Latin, pale.

Morphology: Very fine protoplasmic spirals 0.25 to 0.3 by 6 to 14 microns.

Spiral amplitude: 1.0 micron, regular, fixed.

Spiral depth: 0.5 to 1.0 micron.

Terminal spiral filament present.

Weakly refractive in living state by dark field illumination. May appear as a series of bright dots or string of radiant beads with poor dark field illumination.

Staining: Stain with difficulty except with Giemsa's stain by which they appear pink or rose. Appear black with silver impregnation methods.

Motility: Sluggish, drifting motion, stiffly flexible, rarely rotating.

Trypsin digestion: Resistant for many days.

Bile salts (10 per cent): Disintegration complete.

Saponin (10 per cent): Broken up in time.

Cultivation: With difficulty under strict anaerobiosis in ascitic fluid with addition of fresh rabbit kidney.

Habitat: The cause of syphilis in man. Can be transmitted experimentally to anthropoid apes and rabbits.

2. **Treponema pertenue** Castellani. (Castellani, Jour. Trop. Med., *8*, 1905, 253; *Spirochaeta pertenuis* Castellani, Jour. Ceylon Branch Brit. Med. Assoc., June, 1905; *Spirochaeta pallidula* Castellani, Brit. Jour. Med., *2*, Nov., 1905, 1330; *Spirochaete pertenuis* Lehmann and Neumann, Bakt. Diag., 5 Aufl., *2*, 1912, 677; *Spironema pertenue* Gross, Archiv f. Protistenk., *24*, 1912, 115; *Treponema pallidulum* Brumpt, Nouveau Traité de Médecine, Paris, *4*, 1922, 508.) From Latin, very fine.

Morphologically indistinguishable from *Treponema pallidum*.

Cultivable under anaerobic conditions in the same medium used for *Treponema pallidum*.

Habitat: The cause of yaws—tropica frambesia. Patients with the disease give a positive Wassermann test. Prbobably transmitted by contact.

3. **Treponema microdentium** Noguchi. (Jour. Exp. Med., *15*, 1912, 81.) From Greek *mikros*, small and Latin, teeth.

The organism is less than 0.25 micron in thickness in the middle and tapers toward each extremity, which is pointed. The length varies with age but may reach 8 microns and show an average of 14 curves. Sometimes a long, thin flagella-like projection is observed at each extremity.

Growth occurs under anaerobic conditions in serum water medium containing fresh tissue. The serum is slightly coagulated and gives off a strong, fetid odor.

Habitat: Normal oral cavity.

4. **Treponema mucosum** Noguchi. (Jour. Exp. Med., *16*, 1912, 194; *Spirochaeta mucosa* Pettit, Contribution à l'Étude des Spirochétidés, Vanves, II, 1928, 190.) From Latin, mucous.

Spirals: 0.25 to 0.3 by 8 to 12 microns. The number of curves varies from 6 to 8. Both extremities are sharply pointed and often possess a minute curved projection, 8 to 10 microns long.

Cultivable under anaerobic conditions, forming mucin.

The cultures give off a strong, putrid odor.

Takes the red in Giemsa's stain.

Strict anaerobe.

Source: From pus in a case of pyorrhoea.

Habitat: Found in pyorrhea alveolaris. It possesses pyogenic properties.

5. **Treponema calligyrum** Noguchi. (Noguchi, Jour. Exp. Med., *17*, 1913, 96; *Spirochaeta calligyra* Zuelzer, 1925, in Prowazek, Hand. d. path. Protoz., *3*, 1931, 1673.) From M. L., with beautiful circles.

Morphology: 0.35 to 0.4 by 6 to 14 microns, average 9 to 12 microns. Spirals are regular and deep but more rounded than those of *Treponema pallidum*. The organism is of uniform width until near the extremities which end in sharp points with delicate projections.

Motility: Active, chiefly rotating.

Stains reddish-violet with Giemsa's stain.

Cultivation: Grows under anaerobic conditions.

Not pathogenic for monkeys or rabbits.

Source: From smegma.

Habitat: Lesions and membranes of the pudenda.

6. **Treponema genitalis** Noguchi. (*Treponema minutum* Noguchi, Jour. Exp. Med., *27*, 1918, 671; not *Treponema minutum* Dobell, Arch. f. Protistenk., *26*, 1912, 151; not *Treponema minutum* Castellani, 1916; Noguchi, Laboratory Diagnosis of Syphilis, New York, 1923, 260; *Spirochaeta minutum* Zuelzer, 1925, in Prowazek, Handb. d. path. Protoz., *3*, 1931, 1673; *Spirochaeta genitalis* Séguin and Vinzent, Ann. Inst. Past., *61*, 1938, 255.) From Latin, genital.

Morphology: 0.25 to 0.3 by 3 to 14 microns. Spirals round, regular and shallow. Smaller than *Treponema pallidum* and spirals are closer together.

Motility: Active.

Culture: Grows anaerobically and requires fresh tissue.

Non-pathogenic.

Habitat: Found on male and female genitalia.

7. **Treponema carateum** Brumpt. (Treponema de un caso de pinta, Saenz, Grau Triana and Alfonso, Arch. de Med. Int., Havana, *4*, 1938, 3; Brumpt, Compt. Rend. Soc. Biol., Paris, *130*, 1939, 942; *Treponema herrejoni* León y Blanco, Rev. de Med. Trop. y Parasitol., Habana, *6*, 1940, 5; *Treponema pictor* Pardo-Castello, Rev. de Med. Trop. y Parasitol.

Habana, *6*, 1940, 117; *Treponema pintae* Curbelo, Elementos de Bacteriología Médica, 1941, 34.) From carate, spotted sickness.

Description taken from León y Blanco (*loc. cit.*).

Cylindrical: 0.25 to 0.30 by 7.8 to 36.8 microns, average length 17.8 microns. With sharp-pointed ends.

Spiral amplitude: 1 micron, regular.

Spiral depth: 0.8 to 1.0 micron.

Number of waves, 6 to 27, according to length. Ten to twelve (Brumpt, *loc. cit.*).

Actively motile. At times undulating or creeping movements are shown.

Staining reactions: Readily takes silver impregnations, Giemsa's stain, carbol-fuchsin and gentian violet.

Saponin (10 per cent): Disintegrates in six hours at room temperature. Same result with sodium taurocholate (10 per cent) and with bile.

Distilled water: Produces swelling.

Loses motility on heating for 15 minutes at 50°C or for 3 hours at 41°C.

Wassermann, Kahn and Meinicke reactions positive.

Has not yet been cultivated artificially. Experimental transmission unsuccessful so far.

Source: From the border of cutaneous lesions of persons having pinta (spotted sickness).

Habitat: The cause of pinta (or carate). Common in Mexico and Colombia. Also found in other northern countries of South America, in Central America and the West Indies. Rare in Cuba. Possibly found in other tropical regions of the world.

8. **Treponema cuniculi** Noguchi. (*Spirochaeta paraluis cuniculi* Jakobsthal, Dermatol. Wchnschr., *71*, 1920, 569; Noguchi, Jour. Amer. Med. Assoc., *77*, 1921, 2052; also see Noguchi, Jour. Exp. Med., *35*, 1922, 395; *Treponema pallidum* var. *cuniculi* Klarenbeek, Cent. f. Bakt., I Abt., Orig., *87*, 1921, 203; *Spirochaeta cuniculi* Seraditi, Marie and Isaien, Compt. rend. Soc. Biol., Paris, *85*, 1921, 51; *Spirochaeta pallida* var. *cuniculi* Zuelzer, 1925, in Prowazek, Handb. d. path. Protoz., *3*, 1931, 1765; *Spirochaeta paraluis* Pettit, Contribution à l'Étude des Spirochétidés, Vanves, II, 1928, 91; *Spirochaeta paraluis-cuniculi* Hindle, Med. Res. Council Syst. of Bact., *8*, 1931, 187.) From Latin, rabbit.

Description from Noguchi (*loc. cit.*).

Closely resembles *Treponema pallidum*, but longer.

Width 0.25 micron; length 10 to 16 microns; long specimens up to 30 microns frequent.

Spirals 8 to 12 in number, regular, deep.

Spiral amplitude 1 to 1.2 microns.

Spiral depth 0.6 to 1.0 micron.

Delicate terminal filament at one, sometimes both, ends.

Often forms entangled masses of long threads; occurs sometimes in a stellate arrangement.

Staining properties same as for *Treponema pallidum*. Both readily stained by ordinary basic analine dyes when fixed in a buffered formaldehyde solution.

Wassermann reaction negative.

Pathogenesis: Disease transmissible to healthy rabbits, producing papular lesions in the genitoperineal region. Not pathogenic for monkeys, mice or guinea pigs.

Source: From lesions in the genitoperineal region of five rabbits.

Habitat: The cause of rabbit spirochetosis.

Appendix: Many of the species in this appendix are so inadequately described that it is not certain that they belong in this group.

Microspironema legeri Duboscq and Lebailly. (Duboscq and Lebailly, Compt. rend. Acad. Sci. Paris, *154*, 1912, 662; *Treponema legeri* Zuelzer, 1925, in Prowazek, Handb. d. path. Protoz., *3*, 1931, 1683.) From a fish, *Box boops*.

Spirochaeta microgyrata Loewenthal. (Loewenthal, Berl. klin. Wochnschr., *43*, 1906, 283; *Spironema microgyrata* Nogu-

chi, Jour. Exp. Med., *27*, 1918, 584; *Spiroschaudinnia microgyrata* Castellani and Chalmers, Man. Trop. Med., 3rd ed., 1919, 454; *Treponema microgyratum* Brumpt, Nouveau Traité de Médecine, *4*, 1922, 506.) From cancerous ulcers of man, dogs, and mice. Regarded by Hoffmann and Prowazek (Cent. f. Bakt., I Abt., Orig., *41*, 1906, 819) as identical with *Spirochaeta dentium*.

Spirochaeta parotitidis Lehmann. (In Lehmann and Neumann, Bakt. Diag., 7 Aufl., *2*, 1927, 580.) Pathogenic, producing a disease similar to mumps in experimental animals (cats) and causing parotitis and orchitis in apes.

Spirochaeta penortha Beveridge. (Austral. Jour. Expt. Biol. and Med. Sci., *14*, 1936, 307.) This organism is also called *Treponema podovis* according to Shahan, in Keeping Livestock Healthy, U. S. D. A. Yearbook of Agriculture, Part 6, 1942, 830.) Present as an accessory factor in foot-rot of sheep. Also see *Actinomyces nodosus*.

Spirochaeta phlebotomi Pringault. (Compt. rend. Soc. Biol., Paris, *84*, 1921, 209.) From the sand fly, *Phlebotomus perniciosus*.

Spirochaeta pseudopallida Mulzer. (Mulzer, Berl. klin. Wchnschr., *42*, 1905, 1144; *Spiroschaudinnia pseudopallida* Castellani and Chalmers, Man. Trop. Med., 3rd ed., 1919, 449; *Treponema pseudopallidum* Brumpt, Nouveau Traité de Médecine, Paris, *4*, 1922, 511.) Found in ulcerating carcinomata.

Spirochaeta skoliodonta Hoffmann. (Hoffmann, Cent. f. Bakt., I Abt., Orig., *86*, 1920, 137; *Spirochaeta acuta* Kritchevsky and Séguin, 1920, according to Séguin and Vinzent, Ann. Inst. Past., *67*, 1941, 62; *Treponema skoliodontum* Noguchi, in Jordan and Falk, Newer Knowledge Bact. and Immun., 1928, 481.) From the peritoneal exudate of a guinea pig. One of the smallest known spirochetes. From the oral cavity.

Spirochaeta subtilis Castellani. (Castellani, 1907; *Spiroschaudinnia subtilis* Castellani and Chalmers, Man. Trop. Med., 3rd ed., 1919, 450; *Treponema subtile* Brumpt, Nouveau Traité de Médecine, Paris, *4*, 1922, 514; *Spironema subtilis* Pettit, Contribution à l'Étude des Spirochétidés, Vanves, II, 1928.) From the oral mucosa and from intestinal contents. May be a synonym of *Spirochaeta dentium*.

Spirochaeta urethralis Castellani. (Castellani, 1915; *Treponema urethrale* Castellani and Chalmers, Man. Trop. Med., 3rd ed., 1919, 1944.) From a purulent urethral discharge.

Spirochaeta vaccinae Bonhoff. (Bonhoff, Berl. klin. Wochnschr., *42*, 1905, 1142; *Treponema vaccinae* Brumpt, Nouveau Traité de Médecine, Paris, *4*, 1922, 515.) From vaccinia.

Spirochaeta vaginalis Macfie. (Macfie, Ann. Trop. Med. and Parasitol., *10*, 1916, 315; *Treponema vaginalis* Brumpt, Nouveau Traité de Médecine, Paris, *4*, 1922, 514.) From a case of vaginitis in a Gold Coast native.

Spirochaete hartmanni Gonder. (Gonder, Cent. f. Bakt., I Abt., Orig., *47*, 1908, 491; *Spironema hartmanni* Gross, Cent. f. Bakt., I Abt., Orig., *65*, 1912, 88; *Spirochaeta hartmanni* Noguchi, Jour. Exp. Med., *34*, 1921, 297; *Treponema hartmanni* Ford, Textb. of Bact., 1927, 990.) From the digestive tract of molluscs, *Pinna spp.*

Spirochaete polyspira Wolff. (Wolff, Cent. f. Bakt., II Abt., *18*, 1907, 448; *Treponema polyspirum* Wolff, *ibid.*; *Spirochaeta polyspira* Pettit, Contribution à l'Étude des Spirochétidés, Vanves, II, 1928, 14.) From rotten potatoes.

Treponema carpanoi Yakimoff and Rastjapin. (Arch. f. Protistenk., *71*, 1930, 543.) From stomatitis of horses.

Treponema cotti Duboscq and Lebailly. (Duboscq and Lebailly, Arch. Zool. Expér. et Gén., *10*, 1912, 331; *Microspironema cotti* Duboscq and Lebailly, Compt. rend. Acad. Sci., Paris, *154*, 1912, 662.) From the marine bullhead, *Cottus bubalis*.

Treponema dentium (Miller) Dobell. (Spirochaete im Zahnschleim, Cohn, Beitr. z. Biol. d. Pflanzen, *1*, Heft 2, 1872,

180; *Spirochaete denticola* Flügge, Die Mikroorganismen, 2 Aufl., 1886, 390; *Spirochaete dentium* Miller, Microorganisms of the Human Mouth, Philadelphia, 1890, 80; *Spirillum dentium* Sternberg, Manual of Bact., 1893, 694; *Spirochaeta dentium* Migula, in Engler and Prantl, Die natürl. Pflanzenfam., *1*, 1a, 1895, 35; *Spirochaeta denticola* Arndt, according to Hoffmann and Prowazek, Cent. f. Bakt., I Abt., Orig., *41*, 1906, 819; Dobell, Arch. f. Protistenk., *26*, 1912, 117; *Spironema dentium* Gross, Cent. f. Bakt., I Abt., Orig., *65*, 1912, 88; *Spirochaeta dentinum* McFarland, Pathogenic Bacteria and Protozoa, 7th ed., 1912, 546; *Treponema microdentium* Noguchi, Jour. Exp. Med., *15*, 1912, 81; *Spirochaeta orthodonta* Hoffmann, Deutsch. med. Wochnschr., *46*, 1920, 257; *Spirochaeta microdentium* Heim, Lehr. d. Bakt., 6 and 7 Aufl., 1922, 477; *Treponema denticola* Brumpt, Nouveau Traité de Médecine, Paris, *4*, 1922, 497; *Treponema orthodontum* Noguchi, in Jordan and Falk, Newer Knowledge Bact. and Immun., 1928, 481; *Treponema dentium-stenogyratum* Pettit, Contribution à l'Étude des Spirochétidés, Vanves, II, 1928, 240.) The smallest of the mouth spirochaetes. Non-pathogenic. This term probably includes several morphologically similar species which have not as yet been sufficiently characterized.

Treponema drosophilae Chatton. (Compt. rend. Soc. Biol., *73*, 1912, 212.) From *Drosophila confusa*. Six to thirty microns in length, tapers at both ends, four spirals, movement helicodal.

Treponema gallicolum Lebailly. (Compt. rend. Soc. Biol., Paris, *75*, 1913, 389.) From the caecum of the hen, *Gallus sp.*

Treponema hilli Duboscq and Grassé. (Compt. rend. Soc. Biol., Paris, *94*, 1926, 34; Arch. Zool. Expér. et Gén., *66*, 1927, 484.) From the surface of the body of a flagellate, *Devescovina hilli*, and in the intestine of a termite, *Glyptotermes iridipennis*. A very small organism.

Treponema intermedium Dobell. (Mittelformen, Lühe, Handb. d. Tropenkrankh., *3*, 1906; see Hoffmann and Prowazek, Cent. f. Bakt., I Abt., Orig., *41*, 1906, 819; Dobell, Arch. f. Protistenk., *26*, 1912, 117; *Treponema macrodentium* Noguchi, Jour. Exp. Med., *15*, 1912, 81; *Spirochaeta media oris* Hoffmann, Deutsch. med. Wochnschr., *46*, 1920, 257; *Treponema medium* Brumpt, Nouveau Traité de Médecine, Paris, *4*, 1922, 505; *Spirochaeta intermedia* Pettit, Contribution à l'Étude des Spirochétidés, Vanves, II, 1928, 146; *Spirochaeta macrodentium* Pettit, *ibid.*, 182; *Spirochaeta media* and *Spironema media* Pettit, *ibid.*, 240.) The middle-sized spirochete of the mouth.

Treponema lari Lebailly. (Compt. rend. Soc. Biol., Paris, *75*, 1913, 389.) Found in the caecum of birds, also in the guinea-pig. Named for one of the birds, *Larus ridibundus*.

Treponema minutum Dobell. (*Treponema sp.* Dobell, Quart. Jour. Microsc. Sci., *52*, 1908, 121; Dobell, Arch. f. Protistenk., *26*, 1912, 151; not *Treponema minutum* Castellani, 1916; not *Treponema minutum* Noguchi, Jour. Exp. Med., *27*, 1918, 671; *Spirochaeta minutum* Zuelzer, 1925, in Prowazek, Handb. d. path. Protoz., *3*, 1931, 1682.) From the large intestines of toads, *Bufo vulgaris*.

Treponema parvum Dobell. (Dobell, Arch. f. Protistenk., *26*, 1912, 117; *Spirochaeta parvum* Zuelzer, 1925, in Prowazek, Handb. d. path. Protoz., *3*, 1931, 1685.) From the intestine of the cockroach, *Stylopyga* (*Blatta*, *Periplaneta*) *orientalis*. Very small organism.

Treponema pavonis Duboscq and Lebailly. (Arch. Zool. Expér. et Gén., *10*, 1912, 331.) From the intestine of the blenny, *Blennius pavo*.

Treponema perexile Duboscq and Lebailly. (Duboscq and Lebailly, Arch. Zool. Expér. et Gén., *10*, 1912, 331; *Spirochaeta perexilis* Hindle, Med. Res. Council Syst. of Bact., *8*, 1931, 180.) From the blood of a marine fish, *Lepadogaster bimaculatus*.

Treponema podovis Ludovic and Blaizot. (Compt. rend. Acad. Sci. Paris, *187*,

1928, 911.) Pathogenic. Cause of a disease in sheep.

Treponema querquedulae Lebailly. (Compt. rend. Soc. Biol., Paris, *75*, 1913, 389.) From caeca of birds. Named for the teal, *Querquedula querquedula*.

Treponema rhinopharyngeum Brumpt. (*Treponema minutum* Castellani, 1916; *Spiroschaudinnia minuta* Castellani and Chalmers, Man. Trop. Med., 3rd ed., 1919, 1881; Brumpt, Nouveau Traité de Médecine, Paris, *4*, 1922, 514.) From man in cases of rhinopharyngitis. Probably a synonym of *Spirochaeta gracilis*.

Treponema rigidum Zinsser and Hopkins. (Jour. Bact., *1*, 1916, 489.) From the tissues in five different strains of rabbit syphilis. Probably a synonym of *Treponema cuniculi*.

Treponema spermiformis Duboscq and Grassé. (Arch. Zool. Expér et Gén., *66*, 1927, 483.) From the rectum of a termite, *Glyptotermes iridipennis*.

Treponema squatarolae Lebailly. (Compt. rend. Soc. Biol., Paris, *75*, 1913, 389.) From the caecum of a bird, *Squatarola squatarola*.

Treponema stylopygae Dobell. (Dobell, Arch. f. Protistenk., *26*, 1912, 117; *Spirochaeta stylopygae* Zuelzer, 1925, in Prowazek, Handb. d. path. Protoz., *3*, 1931, 1685.) From the intestines of the cockroach, *Stylopyga orientalis*.

Treponema tricalle Cohn. (Cohn, 1872, quoted from Castellani and Chalmers, Man. Trop. Med., 2nd ed., 1913, 414.)

Treponema triglae Duboscq and Lebailly. (Arch. Zool. Expér et Gén., *10*, 1912, 331.) From the rectum of a fish, *Trigla lucerna*.

Treponema tropiduri Neiva, Marques da Cunha and Travassus. (Mem. do Inst. Oswaldo Cruz, *6*, 1914, 180.) From the blood of a South American lizard, *Tropidurus torquatus*.

The following species are listed in the index of Castellani and Chalmers, Manual of Tropical Medicine, 2nd ed., 1913, 1718–1719, but are not mentioned in the text (pp. 136–141): *Treponema bovidae*, *T. camelidae*, *T. canidae*, *T. felidae*, *T. hippopotami*, *T. reptilia*, *T. rhinoceri*, *T. selachii*, *T. suidae*, *T. ungulata* and *T. ursidae*.

Genus III. Leptospira *Noguchi.*

(Jour. Exp. Med., *25*, 1917, 753.)

Finely coiled organisms 6 to 20 microns in length. Spirals 0.3 micron in depth and 0.4 to 0.5 micron in amplitude. In liquid medium one or both ends are bent into a semicircular hook each involving $\frac{1}{10}$ to $\frac{1}{8}$ of the organism. Spinning movements in liquid and vermiform in semisolid agar, forward or backward. Seen in living preparations only with dark field. Stain with difficulty except with Giemsa's stain and silver impregnation. Require oxygen for growth.

The type species is *Leptospira icterohaemorrhagiae* (Inada and Ido) Noguchi.

1. **Leptospira icterohaemorrhagiae** (Inada and Ido) Noguchi. (*Spirochaeta icterohaemorrhagiae* Inada and Ido, Tokyo Ijishinski, 1915; Inada, Ido, Hoki, Kaneko and Ito, Jour. Exp. Med., *23*, 1916, 377; *Spirochaeta icterogenes* Uhlenhuth and Fromme, Med. Klin., *11*, 1915, 1202; *Spirochaeta nodosa* Huebner and Reiter, Deutsch. med. Wochnschr., *41*, 1915, 1275; Noguchi, Jour. Exp. Med., *25*, 1917, 755; *Spiroschaudinnia icterohaemorrhagiae* Castellani and Chalmers, Man. Trop. Med., 3rd ed., 1919, 447; *Treponema icterogenes* Gonder and Gross, Arch. f. Protistenk., *39*, 1919, 62; *Spirochaete ictero-haemorrhagica* (sic) Lehmann and Neumann, Bakt. Diag., 6 Aufl., *2*, 1920, 810; *Treponema ictero-hemorragiae* (sic) Brumpt, Nouveau Traité de Médecine, Paris, *4*, 1922, 501; *Treponema nodosum*

Brumpt, *ibid.*, 508; *Leptospira icterogenes* Ford, Textb. of Bact., 1927, 994; *Leptospira nodosa* Ford, *ibid.*, 993.) From Greek *icterus*, jaundice and *hemorrhagiae*, bleeding.

Morphology: 0.25 to 0.3 by 6 to 9 microns and occasionally 20 to 25 microns.

Spiral amplitude: 0.4 to 0.5 micron, regular, rigid.

Spiral depth: 0.3 micron, regular.

Waves: One or more gentle waves throughout entire length. When in liquid media, one or both ends may be semicircularly hooked, while in semisolid media the organism appears serpentine, waved or bent. Very active flexibility.

Terminal filament and flagella absent.

Body stains reddish by Giemsa's stain.

Bile salts (10 per cent): Easily dissolved.

Saponin (10 per cent): Completely resistant.

Cultured easily in medium containing 10 per cent rabbit serum, 0.2 per cent agar, slight amount of hemoglobin in salt or Ringer's solution. Does not grow in surface colonies.

Temperature range: 25° to 37°C. Remains alive longer at 25°C.

Pathogenic for guinea pigs and deermice.

Habitat: The cause of infectious jaundice in man (Weil's disease). Found in the kidneys, urine and blood of wild rats. No insect vector known. Found free-living in water and slime (in mines).

2. **Leptospira hebdomadis** (Ido et al.) Noguchi. (*Spirochaeta nanukayami* Ido, Hoki, Ito and Wani, Nippon Gakkai Zasshi, *5*, 1917, No. 5; *Spirochaeta hebdomadis* Ido, Ito and Wani, Jour. Exp. Med., *28*, 1918, 435; *Spiroschaudinnia hebdomadis* Castellani and Chalmers, Man. Trop. Med., 3rd ed., 1919, 448; Noguchi, Jour. Exp. Med., *30*, 1919, 17; *Treponema hebdomadis* Brumpt, Nouveau Traité de Médecine, Paris, *4*, 1922, 501.) From Latin, seven days.

Morphologically indistinguishable from *Leptospira icteroheamorrhagiae* but can be distinguished serologically.

In man causes less jaundice than *Leptospira icterohaemorrhagiae* and is never fatal.

Identical with Type B, *Leptospira autumnalis*.

Slightly pathogenic for young guinea pigs.

Is carried by the field vole (*Microtus montibelli*).

Habitat: Cause of seven-day fever or gikiyami in Japan.

3. **Leptospira biflexa** (Wolbach and Binger) Noguchi. (*Spirochaeta biflexa* Wolbach and Binger, Jour. Med. Res., *30*, 1914, 23; Noguchi, Jour. Exp. Med., *27*, 1918, 585; *Spirochaeta pseudo-icterogenes* (*aquatilis*) Uhlenhuth and Zuelzer, Cent. f. Bakt., I Abt., Orig., *85*, 1921,* 141; *Spirochaeta pseudoicterogenes* Uhlenhuth and Zuelzer, Klin. Wochnschr., *1*, 1922, 2124; *Spirochaeta pseudo-icterohemorrhagiae* Vinzent, Compt. rend. Soc. Biol., Paris, *95*, 1926, 1472; *Leptospira pseudoicterogenes* Noguchi, in Jordan and Falk, Newer Knowledge Bact. and Immun., 1928, 461.) From Latin, doubly bent.

Size: 0.2 to 0.25 by 5 to 7 microns with tapering ends. Spiral amplitude 0.2 to 0.25 micron. Will pass through an L5 candle filter.

Waves: 22 to 30 in number.

Stains: Best results with Giemsa's stain.

Culture: Can grow in distilled water plus 0.1 per cent potassium nitrate. Rabbit serum in distilled water is best medium.

Optimum temperature 20°C.

Antigenically distinct from *Leptospira icterohaemorrhagiae*.

Not pathogenic.

Source: From tap water, ponds and pools in Berlin.

Habitat: Fresh water.

4. **Leptospira canicola** Okell et al. (Okell, Dalling and Pugh, Vet. Jour., *81*, 1925, 3.) From Latin, dog-dweller.

Morphologically indistinguishable from *Leptospira icterohaemorrhagiae*.

Cultivation: Same as *Leptospira icterohaemorrhagiae*.

Immunology: Some cross-reaction with *Leptospira icterohaemorrhagiae*, but specific in higher dilutions of immune serum.

Source: From blood of dogs.

Habitat: A natural parasite of dogs. Causes a chronic disease of old dogs characterized by uremia, not jaundice. Fatal in 80 per cent of those infected. No intermediate host known. Probably transmitted by direct contact; possibly by healthy carriers.

Appendix: The species listed below are inadequately described and may be identical with those described in full.

Leptospira aqueductum (sic) Ford. (*Spirochaeta pseudoicterogenes aquaeductuum* Uhlenhuth and Zuelzer, Cent. f. Bakt., I Abt., Orig., *85*, 1921, *150; Ford, Textb. of Bact., 1927, 998.) From fresh water of aqueducts. Probably a synonym of *Leptospira biflexa*.

Leptospira asthenoalgiae Carbo-Noboa. (Bull. Inst. Past., *22*, 1924, 898.) From blood, urine and organs of persons having dengue.

Leptospira autumnalis Topley and Wilson. (Akiyami Type A, Koshina, Shiwozawa and Kitayama, Japan. Med. Wld., *4*, 1924, 268; see also Jour. Exp. Med., *42*, 1925, 873; Topley and Wilson, Princip. Bact. and Immun., 1st ed., *2*, 1931, 1202; *Spirochaeta autumnalis A*, quoted from Hindle, Med. Res. Council Syst. of Bact., *8*, 1931, 312; *Spirochaeta autumnalis* Hindle, *ibid.*) The cause of akiyami or harvest sickness in Japan. May be identical with *Leptospira icterohaemorrhagiae*.

Leptospira bataviae. (1925, quoted from Gispen and Schüffner, Cent. f. Bakt., I Abt., Orig., *144*, 1939, 427.) From a case of fever in the Dutch East Indies. Probably a synonym of *Leptospira hebdomadis*.

Leptospira biliohemoglobinuriae (Blanchard and Lefrou) Noguchi. (*Spirochaeta bilio-hemoglobinuriae* Blanchard and Lefrou, Compt. rend. Acad. Sci., Paris, *175*, 1922, 602; Noguchi, in Jordan and Falk, Newer Knowledge Bact. and Immun., 1928, 490.) From cases of blackwater fever.

Leptospira bonariensis Savino and Rennella. (Rev. Inst. Bact. "Dr. Carlos G. Malbram", *12*, 1944, 182.) From gray rats.

Leptospira bovis Noguchi. (New York State Med. Jour., *22*, 1922, 426.) From the gastric mucosa of the ox.

Leptospira couvyi Gomes de Faria. (Compt. rend. Soc. Biol., Paris, *90*, 1924, 55; *Spirochaeta couvyi* Hindle, Med. Res. Council Syst. of Bact., *8*, 1931, 317.) From the blood of persons having dengue.

Leptospira dentale Perrín. (Rev. Mex. de Biol., *2*, 1922, 171.) Found in the pus of bucco-maxillary gangrene.

Leptospira grippo-typhosa Topley and Wilson. (Topley and Wilson, Princip. Bact. and Immun., 2nd ed., 1936, 728; *Spirochaeta dmitrovi* Rimpau, Schlossberger and Kathe, Cent. f. Bakt., I Abt., Orig., *141*, 1938, 320.) The cause of swamp fever in Europe. Probably synonymous with *Leptospira hebdomadis*. Also see Baschenin, Cent. f. Bakt., I Abt., Orig., *113*, 1929, 438 and 450; Dinger and Verschaffelt, Ann. Inst. Past., *45*, 1930, 396.

Leptospira haemoglobinuriae Schüffner. (Geneesk. Tijdschr. Ned. Indië, *58*, 1918, 352; *Spirochaeta haemoglobinuriae* Hindle, Med. Res. Council Syst. of Bact., *8*, 1931, 314.) From the blood of a Javanese patient suffering from an attack of blackwater fever.

Leptospira icterohemoglobinuriae Schüffner. (Schüffner, Geneesk. Tijdschr. v. Ned. Indië, *58*, 1918, 352, according to Pettit, Contribution à l'Étude des Spirochétidés, Vanves, II, 1928; *Spirochaeta icterohemoglobinuriae* Schüffner, Mededeel. Burgerl. Geneesk. Dienst in Nederl. Indië, *58*, 1918, 7 (according to Blanchard and Lefrou, Compt. rend. Acad. Sci., Paris, *175*, 1922, 602); *Treponema icterohemoglobinuriae* Brumpt,

Nouveau Traité de Médecine, Paris, *4*, 1922, 501.) From the blood in a case of blackwater fever.

Leptospira interrogans (Stimson) Noguchi. (*Spirochaeta interrogans* Stimson, U. S. Public Health Rept., Part I, *22*, 1907, 541; *Leptospira icteroides* Noguchi, Jour. Exp. Med., *29*, 1919, 581; *Treponema interrogans* Brumpt, Nouveau Traité de Médecine, Paris, *4*, 1922, 505; *Treponema icteroides* Brumpt, *ibid.*; *Spirochaeta icteroides* Lehmann and Neumann, Bakt. Diag., 7 Aufl., *2*, 1927, 576; Noguchi, in Jordan and Falk, Newer Knowledge Bact. and Immun., 1928, 454.) Noguchi (1928) regards this species as identical with *Leptospira icterohaemorrhagiae.*

Leptospira pettiti (Fiessinger) Hindle. (*Spirochaete pettiti* Fiessinger, Ann. de Méd., *5*, 1918, 156; *Treponema pettiti* Brumpt, Nouveau Traité de Médecine, Paris, *4*, 1922, 510; Hindle, Med. Res. Council Syst. of Bact., *8*, 1931, 316; *Spirochaeta pettiti* Hindle, *idem*; not *Spirochaeta pettiti* Row, Jour. Trop. Med. and Hyg., 1922, 364.) From urine. Morphologically indistinguishable from *Leptospira icterohaemorrhagiae.*

Leptospira pyrogenes Vervoort. (Vervoort, Geneesk. Tijdschr. v. Ned. Indië, *63*, 1923, 800; *Spirochaeta febrilis* Vervoort, Rep. Far East. Assoc. Trop. Med., London, 1923, 683; *Spirochaeta pyrogenes* Hindle, Med. Res. Council Syst. of Bact., *8*, 1931, 314.) From the blood of persons suffering from dengue-like fevers in Sumatra. Pathogenic.

Leptospira saxkoebing Petersen. (Acta Path. et Microbiol. Scand., *21*, 1944, 165.) A new serological type.

Leptospira salina Ford. (*Spirochaeta pseudoicterogenes salina* Uhlenhuth and Zuelzer, Cent. f. Bakt., I Abt., Orig., *85*, 1921, *150; Ford, Textb. of Bact., 1927, 998.) From salt water.

Leptospira trimerodonta (Hoffmann) Noguchi. (*Spirochaeta trimerodonta* Hoffmann, Deutsch. med. Wochnschr., *46*, 1920, 257; *Leptospira dentium* Hoffmann, *ibid.*, 625; *Leptospira buccalis* Fontana, according to Pettit, Contribution à l'Étude des Spirochétidés, Vanves, II, 1928, 232; Noguchi, in Jordan and Falk, Newer Knowledge Bact. and Immun., 1928, 461.) From the oral cavity. May be synonymous with *Leptospira icterohaemorrhagiae.*

Spirochaeta anthropopitheci Wilbert and Delorme. (Ann. Inst. Past., *41*, 1927, 1147.) Pathogenic for chimpanzees in French Guinea. Probably identical with *Leptospira icterohaemorrhagiae.*

Spirochaeta elusa Wolbach and Binger. (Wolbach and Binger, Jour. Med. Res., *30*, 1914, 9; *Treponema elusum* Bergey et al., Manual, 1st ed., 1923, 428.) From pond water. Not pathogenic. For a description of this species, see Bergey et al., Manual, 5th ed., 1939, 957.

Spirochaeta ictero-uraemia canis Klarenbeek. (Tijdschr. Diergeneesk., *55*, 1928, 227.) From the kidneys of dogs. Pathogenic for guinea pigs. May be synonymous with *Leptospira icterohaemorrhagiae* or *L. canicola.*

Spirochaeta pseudohebdomadis Zuelzer. (1925, in Prowazek, Handb. d. path. Protoz., *3*, 1931, 1671.) Probably identical with *Leptospira hebdomadis.*

Spirochaeta trimeres Hoffmann. (Deutsch. med. Wochnschr., *46*, 1920, 257.) From the oral cavity. May be synonymous with *Leptospira trimerodonta.*

SUPPLEMENT NO. 1.

ORDER RICKETTSIALES

April, 1947.

ORDER RICKETTSIALES GIESZCZYKIEWICZ.

(Bull. Intern. Acad. Polon. Sci., Classe Math. Nat., B(1), 1939, 9–30.)

Small, rod-shaped, coccoid, spherical and irregularly-shaped microorganisms which stain lightly with aniline dyes. Gram-negative. Usually not filterable. Cultivated outside the body, if at all, only in living tissue, embryonated eggs or rarely in media containing body fluids. Parasitic organisms intimately associated with tissue cells and erythrocytes, chiefly in vertebrates and often in arthropods which act as vectors. The intracellular parasites of *Protozoa* may also belong here. May cause diseases in man or animals, or both.

Key to the families of order **Rickettsiales.**

I. Intracellular parasites, or parasites intimately associated with tissue cells. Do not occur in erythrocytes. Frequently cause diseases of vertebrates transmitted by arthropod vectors.
  Family I. *Rickettsiaceae*, p. 1083.

II. Facultative intracellular or extracellular parasites found characteristically in or on the erythrocytes of vertebrates. May be transmitted by arthropod vectors.
  Family II. *Bartonellaceae*, p. 1100.

III. Intracellular parasites found in vertebrate tissues and not transmitted by arthropod vectors.
  Family III. *Chlamydozoaceae*, p. 1114.

*FAMILY I. RICKETTSIACEAE PINKERTON.

(Pinkerton, Parasitology, *28*, 1936, 186; *Rickettsiales* Buchanan and Buchanan, Bacteriology, 4th ed., New York, 1938, 49.)

Small, often pleomorphic, rod-shaped, ovoid, coccoid and coccus-shaped bacterium-like organisms, intimately associated with arthropod tissues, usually in an intracellular position. Stain lightly with aniline dyes. Gram-negative. Have not been cultivated to date in cell-free media. May be parasitic to man and other animals causing diseases (typhus and related ills) that are transmitted by arthropod vectors (lice, fleas, ticks, mites and probably other ectoparasites).

Key to the genera of family **Rickettsiaceae.**†

I. Cells rod-shaped, ellipsoidal and coccoid.
  A. Non-filterable.
    Genus I. *Rickettsia*, p. 1084.
  B. Filterable.
    Genus II. *Coxiella*, p. 1092.

II. Cells spherical, occasionally elongated.
    Genus III. *Cowdria*, p. 1094.

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* Prepared by Dr. Ida A. Bengtson (retired), National Institute of Health, Bethesda, Maryland, November, 1946. Through the courtesy of Dr. Edward A. Steinhaus much use was made of material from his book, Insect Microbiology, Ithaca, 1946, 763 pp. before it was generally available.

† Includes only those rickettsiae which have been rather completely studied. For additional rickettsiae, see appendix.

Genus I. **Rickettsia** *da Rocha-Lima.*

(Berl. klin. Wchnschr., *53*, 1916, 567–569.) Named for Howard Taylor Ricketts who lost his life studying typhus fever.

Small, often pleomorphic, rod-shaped to coccoid organisms occurring intracytoplasmically in lice, fleas, ticks and mites, or sometimes intranuclearly. Stain lightly with aniline dyes. Gram-negative. Non-filterable. Have not been cultivated in cell-free media. Parasites of man and animals which are the etiological agents of epidemic typhus, murine or endemic typhus, Rocky Mountain spotted fever, tsutsugamushi disease, rickettsialpox and other diseases.

For reasons that are discussed elsewhere (Bengtson, Jour. Bact., *53*, 1947, 325) the genus *Dermocentroxenus* has been united with the genus *Rickettsia*.

The type species is *Rickettsia prowazekii* da Rocha-Lima.*

Key to the species of genus **Rickettsia.**

I. Louse-borne.
   1. *Rickettsia prowazekii.*

II. Flea-borne.
   2. *Rickettsia typhi.*

III. Tick-borne.
   3. *Rickettsia rickettsii.*
   4. *Rickettsia conorii.*

IV. Mite-borne.
   5. *Rickettsia tsutsugamushi.*
   6. *Rickettsia akari.*

1. **Rickettsia prowazekii** da Rocha-Lima. (da Rocha-Lima, Berl. klin. Wchnschr., *53*, 1916, 567; *Rickettsia exanthematotyphi* Kodama, Kitasato Arch. Exper. Med., *9*, 1932, 360; *Rickettsia prowazeki* var. *prowazeki* Pinkerton, Parasitology, *28*, 1936, 186; *Rickettsia prowazeki* sub-species *prowazeki* Philip, Amer. Jour. Hyg., *37*, 1943, 307.) Named for S. von Prowazek who lost his life studying typhus fever.

Minute coccoid, ellipsoidal and ovoid forms to short rods, sometimes long rods and occasionally filamentous forms, often in pairs and occasionally in chains. In infected lice the minute coccoid and paired coccoid forms predominate over the short and long rods and the filamentous forms which are up to 40 microns in length. Single elements 0.25 by 0.4 to 0.3 by 0.45 micron. Pairs range from 0.25 by 0.7 to 0.3 by 1.1 microns. In yolk sacs the organisms vary in size from minute coccoid forms in heavily infected tissue to rod forms resembling small bacteria in lightly infected tissue. Within the same smear of infected mammalian cells and in chick embryo tissue the organisms are quite uniform in size and morphology. Occur intracytoplasmically in vascular endothelial cells and in serosal cells. Non-motile.

* The Editors of the MANUAL follow Recommendation XL of the International Botanical Code (see p. 59) in regard to the endings used for specific names. This calls for the use of the *ii* ending for epithets taken from the name of a man ending in a consonant (except names ending in *er*). Some students of the *Rickettsiaceae* follow the International Rules of Zoological Nomenclature which use *ii* only in case the name used was employed and declined in Latin. Zoologists use the single *i* for modern patronymics based on all other names of men.

The organisms are colored purplish with the Giemsa stain, the two individuals of a pair being connected by a zone of faintly blue stained material. They are colored blue with Castañeda stain (Jour. Inf. Dis., *47*, 1930, 416) and bright red against a blue background with Machiavello stain (Rev. Chilena de Hig. y Med. Prev., *1*, 1937, 101). Gram-negative.

Cultivation: In plasma tissue cultures of mammalian cells, in the louse intestine, in modified Maitland media with and without agar, on chorio-allantoic membrane and yolk sac of chick embryo, the latter being currently the medium of choice.

Optimum temperature 32°C in plasma tissue culture, 35°C in chick embryo cells.

Immunology: Immunity prolonged but may not be complete in man. Indistinguishable from endemic (murine) typhus in cross immunity tests in guinea pigs, but distinguishable from Rocky Mountain spotted fever and other rickettsial diseases in such tests. Neutralizing antibodies are found in the serum of recovered guinea pigs and convalescent humans up to 2 to 3 weeks after defervescence. Killed vaccines produced from infected lice and from infected yolk sacs afford a high degree of protection against the disease. Hyperimmune antisera for therapeutic use have been produced in rabbits by injection with infected yolk sac suspensions and in horses and donkeys with infected mouse lung suspensions.

Serology: Strains from various parts of the world are closely related as determined by complement fixation; are distinguishable from other rickettsiae by agglutination, complement fixation and precipitin tests; have a common antigenic factor (alkali stable polysaccharide) with *Proteus* OX19; and have a soluble antigen in yolk culture.

Lethal effect: Heavily infected yolk sac cultures injected intravenously or intraperitoneally are fatal to white mice in a few hours.

Resistance to chemical and physical agents: Readily inactivated by heat and chemical agents. A temperature of 50°C kills the organism in 15 to 30 minutes, and 0.5 per cent phenol and 0.1 per cent formalin kill the organism.

Pathogenicity: Pathogenic for man, apes, monkeys, guinea pigs, cotton rats, gerbilles, the louse (*Pediculus humanus*). Inapparent infections occur in white mice, white rats and rabbits. A characteristic febrile reaction with no mortality and without testicular swelling occurs in the guinea pig. Passage in guinea pigs is accomplished by transfer of blood or brain from infected animals. Causes a febrile disease with exanthema and high mortality in man.

Source: Seen in the blood of typhus patients and in smears of epithelial cells of the intestinal tract of lice fed on typhus patients.

Habitat: The body louse (*Pediculus humanus* var. *corporis*), head louse (*Pediculus humanus* var. *capitis*) and *Pedicinus longiceps*. The etiological agent of epidemic typhus (European typhus, classical typhus, typhus exanthematicus).

2. ***Rickettsia typhi** (Wolbach and Todd) Philip. (*Dermacentroxenus*

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* Some may regard the binomial *Rickettsia typhi* as invalid because of its previous use by do Amaral and Monteiro for the organism causing eastern Rocky Mountain spotted fever. However, because the binomial *Dermacentroxenus typhi* Wolbach and Todd clearly has priority and because the binomial proposed by do Amaral and Monteiro has never come into general use, *Rickettsia typhi* Philip has been accepted for use in the MANUAL. If Philip's binomial had been rejected, then it would have been necessary to accept *Rickettsia manchuriae* Kodama et al. as this appears to have priority over the more generally used *Rickettsia mooseri* Monteiro.—Editors.

typhi Wolbach and Todd (not Tood), Ann. Inst. Past., *34*, 1920, 158; minute intracellular bodies, Mooser, Jour. Inf. Dis., *43*, 1928, 261; *Rickettsia manchuriae* Kodama, Takahashi and Kono, Saikingaku-Zasshi (Jap.), No. 426, 427, Aug. and Sept., 1931; see Kodama, Kono and Takahashi bibliography, Kitasato Arch. Exper. Med., *9*, 1932, 95; *Rickettsia mooseri* Monteiro, Mem. Inst. Butantan, *6*, 1931, 97 (pub. July, 1932), see do Amaral and Monteiro, bibliography, *ibid.*, *7*, 1932, 367; *Rickettsia exanthematofebri* Kodama, Kitasato Arch. Exp. Med., *9*, 1932, 360; *Rickettsia muricola* Monteiro and Fonseca, Brazil Med., *46*, 1932, 1032; *Rickettsia murina* and *Rickettsia fletcheri* Megaw, Trans. Roy. Soc. Trop. Med. Hyg., *29*, 1935, 105; *Rickettsia prowazeki* var. *mooseri* Pinkerton, Parasitology, *28*, 1936, 185; *Rickettsia prowazeki* sub-species *typhi* Philip, Amer. Jour. Hyg., *37*, 1943, 304; *Rickettsia typhi* Philip, *idem*; not *Rickettsia typhi* do Amaral and Monteiro, Rev. Sud. Amér. de Méd. et Chirug., *4*, 1933, 806.) From M. L. *typhus*, typhus.

Resembles *Rickettsia prowazekii* in morphological and staining properties. Non-motile. Gram-negative.

Cultivation: May be cultivated in plasma tissue culture of mammalian cells, in modified Maitland media with and without agar, in fleas, in the peritoneal cavity of X-rayed rats, in the lungs of white mice and in white rats following intranasal inoculation, in the lungs of rabbits following intratracheal inoculation, in the chorio-allantoic membrane and the yolk sac of the chick embryo.

Optimum temperature 35°C in chick embryo cells.

Immunology: Prolonged immunity in man and animals following infection. Complete cross immunity between epidemic and endemic typhus in guinea pigs recovered from infections with *Rickettsia prowazekii* and *Rickettsia typhi*. No cross immunity between endemic typhus and Rocky Mountain spotted fever, Q fever or tsutsugamushi disease in guinea pigs.

Serology: Distinguishable from the rickettsiae of spotted fever, Q fever and tsutsugamushi disease by complement fixation, agglutination and precipitin tests, less readily from *R. prowazekii* by these tests. Has common antigenic factor with *Proteus* OX19, and soluble antigen in yolk-sac cultures.

Lethal effect: Heavily infected yolk sac cultures injected intravenously or intraperitoneally fatal to white mice in a few hours.

Pathogenicity: Pathogenic for man, apes, monkeys, rabbits, guinea pigs, white rats, eastern cotton rat, white mice, gerbilles. Other susceptible animals include the woodchuck, house mouse, meadow mouse, white-footed mouse, old-field mouse, cotton mouse, golden mouse, wild rat (*Rattus norvegicus*), wood rat, rice rat, flying squirrel, gray squirrel, fox squirrel, gophers, cotton-tail rabbit, swamp rabbit, chipmunk, skunk, opossum and cat. A characteristic febrile reaction occurs in the guinea pig with testicular swelling without ulceration, after intraperitoneal inoculation. Passage in guinea pigs is accomplished by transfer of testicular washings or blood from infected animals. Cause of a febrile disease with exanthema in man, with low mortality.

Source: Seen by Wolbach and Todd (*loc. cit.*) in the endothelial cells of the capillaries, arterioles and veins in sections of skin from cases of Mexican typhus (tabardillo). Also described by Mooser (*loc. cit.*) in sections and smears of the proliferated tunica vaginalis of guinea pigs reacting to the virus of Mexican typhus.

Habitat: Infected rat fleas (*Xenopsylla cheopis*, *Xenopsylla astia*), infected chicken fleas (*Echidnophaga gallinacea*) found on wild rats, and the rat louse (*Polyplax spinulosus*). Wild rats and field mice act as the reservoir of infection. The etiological agent of en-

demic (murine) typhus which is transmitted to man by the rat flea.

3. **Rickettsia rickettsii** (Wolbach) Brumpt. (*Dermacentroxenus rickettsi* Wolbach, Jour. Med. Res., *41*, 1919–20, 87; *Rickettsia rickettsi* Brumpt, Précis de Parasitologie, 3rd ed., 1922, 757; *Rickettsia brasiliensis* Monteiro, Mem. Inst. Butantan, *6*, 1931, 3; **Rickettsia typhi* do Amaral and Monteiro, Rev. Sud. Amér. de Méd. et Chirurg., *4*, 1933, 806; *Dermacentroxenus rickettsi* var. *brasiliensis* Pinkerton, Parasitology, *28*, 1936, 186.) *Rickettsia dermacentroxenus*, a corruption of *Dermacentroxenus rickettsi*, though widely used, has no genuine taxonomic standing. Named for Howard Taylor Ricketts, who first transmitted the disease from human cases to monkeys and guinea pigs with the production of characteristic symptoms and lesions and fatal effect.

Minute paired organisms surrounded by a narrow clear zone or halo and often lanceolate, resembling in appearance a minute pair of pneumococci. Approximately 0.2 to 0.3 micron by 1 micron. Non-motile.

In smears of mammalian tissues there occur in addition to the lanceolate forms, slender rod-shaped forms stained blue with the Giemsa stain, sometimes exhibiting polar granules, stained purplish or reddish. There are also minute pale blue-staining rounded forms. In the tick there are three forms: (1) Pale blue bacillary forms curved and club-shaped, (2) smaller bluish rods with deeply staining chromatoid granules and (3) more deeply staining, purplish, lanceolate forms. A very minute form may appear in tightly packed masses in the nuclei of the cells. Occurs in the cytoplasm and nucleus in all types of tissue in the tick and in the vascular endothelium, in the serosal cells of the peritoneal cavity, in the smooth muscle cells of arteriolar walls and in the macrophages of mammals.

In yolk sac cultures and in the Maitland media cultures, bacillary forms often occur in pairs. In single smears from infected yolk sacs, the rickettsiae are rather uniform in size and morphology and are definitely larger than *Rickettsia prowazekii* and *Rickettsia typhi*. They also grow more sparsely. Stain blue with the Castañeda stain and bright red against a blue background of tissue with the Machiavello stain.

Cultivation: May be cultivated in plasma tissue culture of mammalian cells, in Maitland media with and without agar, on the chorio-allantoic membrane and in the yolk sac of the chick embryo, and in ticks.

Optimum temperature 32°C in plasma tissue culture, 35°C in chick embryo cells.

Immunology: Prolonged immunity in man and animals after recovery from infection. Killed vaccines produced from infected ticks and from infected yolk sacs afford considerable protection against the disease. Therapeutic antisera have been produced by the injection of rabbits with tick virus and with infected yolk sac. No cross immunity between spotted fever in guinea pigs recovered from infections with *Rickettsia rickettsii* and typhus in guinea pigs recovered from infections with *Rickettsia prowazekii* and *Rickettsia typhi*. Cross immunity between spotted fever in guinea pigs recovered from infections with *Rickettsia rickettsii* and boutonneuse fever in guinea pigs recovered from infections with *Rickettsia conorii*, but spotted fever vaccine does not protect against boutonneuse fever of the Mediterranean area or against infections with the South African strains of *Rickettsia conorii*.

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* Erroneously applied by do Amaral and Monteiro to the so-called eastern type of Rocky Mountain spotted fever.—Editors.

Serology: Distinguishable from *Rickettsia prowazekii* and *Rickettsia typhi* by complement fixation and agglutination with specific antigens. Distinguishable from *Rickettsia conorii* by complement fixation, though some degree of cross fixation indicates antigenic relationship. Has common antigenic factor with *Proteus* OX19 but not distinguishable from *Rickettsia prowazekii* and *Rickettsia typhi* by Weil-Felix test.

Resistance to chemical and physical agents: Readily inactivated by heat and chemical agents. Destroyed by a temperature of 50°C in 10 minutes, and by 0.5 per cent phenol and 0.1 per cent formalin. Destroyed by desiccation in about 10 hours.

Pathogenicity: Pathogenic for man, monkeys and guinea pigs. Rabbits and white rats are moderately susceptible. Animals susceptible in varying degrees include species of ground squirrels, tree squirrels, chipmunks, cotton-tail rabbits, jack rabbits, snowshoe rabbits, marmots, wood rats, weasels, meadow mice and deer mice. In Brazil the opossum, rabbit, dog and cavy have been found naturally infected and the Brazilian plains dog, capybara, coati and certain bats are also susceptible. Sheep are mildly susceptible.

A febrile reaction occurs in guinea pigs with typical scrotal lesions, involving petechial hemorrhages in the skin, which may become necrotic. Virulent strains kill 80 to 90 per cent of the animals, milder strains kill 20 to 25 per cent. Passage in guinea pigs is accomplished by transfer of blood from infected animals. A febrile reaction accompanied by exanthema occurs in man. Mortality is high in some localities, low in others.

Source: Seen by Ricketts (Jour. Amer. Med. Assoc., *52*, 1909, 379) in the blood of guinea pigs and monkeys experimentally infected with Rocky Mountain spotted fever and in the salivary glands, alimentary sac and ovaries of infected female *Dermacentor* ticks and in their ova.

Habitat: Infected wood tick (*Dermacentor andersoni*) and the dog tick (*Dermacentor variabilis*), also the rabbit tick (*Haemaphysalis leporis-palustris*), *Amblyomma brasiliensis*, *Amblyomma cajennense*, *Amblyomma striatum*, *Amblyomma americanum* and *Ixodes dentatus*. A number of ticks belonging to the genera *Amblyomma*, *Dermacentor*, *Rhipicephalus*, *Ornithodoros* and *Haemaphysalis* have been experimentally infected. The virus is transmissible through the ova of female ticks. The etiological agent of Rocky Mountain spotted fever, Saõ Paulo exanthematic typhus of Brazil, Tobia fever of Colombia and spotted fever of Minas Geraes which are all transmitted to man by the bite of infected ticks.

4. **Rickettsia conorii** Brumpt. (Brumpt, Compt. rend. Soc. Biol., Paris, *110*, 1932, 1199; *Rickettsia megawi* var. *pijperi* do Amaral and Monteiro, Mem. Inst. Butantan, 7, 1932, 361; *Rickettsia blanci* Caminopétros, 1er Cong. Internat. Hyg. Mediterr., Rapports et Compt. rend., *2*, 1932, 202; *Dermacentroxenus rickettsi* var. *pijperi* Mason and Alexander, Onderst. Jour. Vet. Sci. and An. Indust., *13*, 1939, 74; *Dermacentroxenus rickettsi* var. *conori* Mason and Alexander, *ibid.*; *Dermocentroxenus conori* Steinhaus, Insect Microbiology, 1946, 339.) Named for A. Conor who with A. Bruch published in 1910 the first clinical description of boutonneuse fever.

Resembles *Rickettsia rickettsii*. In the tick, diplococcoid and diplobacillary forms predominate, though when the rickettsiae occur in compact masses they are smaller and more coccoid. In tissue cultures the organisms are lanceolate, diplococcoid, and diplobacillary, occurring in the nuclei as well as in the cytoplasm of the cells. Size 0.3 to 0.4 by 1 to 1.75 microns. Non-motile.

Stain purplish with the Giemsa stain,

blue with the Castañeda stain and bright red with a blue background with the Machiavello stain. Gram-negative.

Cultivation: May be cultivated in plasma tissue culture of mammalian cells, in modified Maitland media, and in the yolk sacs of chick embryos.

Immunology: The disease is related immunologically to Rocky Mountain spotted fever with which it cross immunizes, but the spotted fever vaccine does not protect against the Mediterranean and South African strains of boutonneuse fever.

Serology: Distinguishable from *Rickettsia rickettsii* by complement fixation. Has a common antigenic factor with *Proteus* OX19 and OX2.

Pathogenicity: Pathogenic for man and guinea pigs. It is also pathogenic in varying degrees for dogs, horses, spermophiles, monkeys, rabbits, gerbilles and white mice.

Boutonneuse fever is a much less virulent infection for the guinea pig than Rocky Mountain spotted fever. A temperature reaction occurs, accompanied by scrotal swelling but there is no sloughing. There is practically no mortality. Passage in guinea pigs is accomplished by transfer of blood from an infected animal.

In man, localized primary sores (taches noires) and an inflammatory reaction in the regional lymph nodes occur at the site of the tick bite. A febrile reaction with exanthema occurs and mortality is low.

Source: Seen by Caminopétros (Compt. rend. Soc. Biol., Paris, *110*, 1932, 344) in smears from the tunica vaginalis of guinea pigs inoculated with infected dog ticks (*Rhipicephalus sanguineus*).

Habitat: The brown dog tick (*Rhipicephalus sanguineus*) and also the ticks, *Amblyomma hebraeum*, *Haemaphysalis leachi*, *Rhipicephalus appendiculatus* and *Boöphilus decoloratus*. Transmissible through the ova of adult female ticks. The probable animal reservoir is the dog. The etiological agent of boutonneuse fever in man, also known as eruptive, Mediterranean or Marseilles fever and probably Kenya typhus and South African tick bite fever, though the identity of the latter with boutonneuse fever has been questioned.

5. °**Rickettsia tsutsugamushi** (Hayashi) Ogata. (*Theileria tsutsugamushi*

° Some may question the use of this binomial on the ground that Hayashi thought that this species was possibly or probably protozoan in nature when he proposed the name *Theileria tsutsugamushi* (*loc. cit.*) in 1920. However he questions whether *Theileria* is the correct generic name in this paperand accepts the viewpoint that this organism is a rickettsia in a paper published in 1924 entitled, On Rickettsia, Trans. Jap. Path. Soc., *14*, 1924, 198-201. He does not use the binomial *Rickettsia tsutsugamushi* in this paper as indicated by some of his friends in latter papers (Ogata, *loc. cit.*, Kawamura, *loc. cit.*) and apparently first uses it himself in a paper entitled, On Tsutsugamushi Disease, Jap. Path. Soc., *22*, 1932, 686.

Hayashi was not the first to recognize the probable rickettsial nature of the organism of the tsutsugamushi disease (see Blake et al., Amer. Jour. Hyg., *41*, 1945, 257-262) and some even question whether any of the bodies that he found in human lymphocytes from lymph nodes, in mononuclear endothelial phagocytes of the spleen and lymph nodes, and in tissues taken from the region of the mite bite in patients suffering from tsutsugamushi fever were the same as organisms described as *Rickettsia orientalis* by Nagayo et al. (*loc. cit.*).

This position is not supported, however, by Nagayo and his associates who admit that their organisms are identical with some of the organisms described by Hayashi. Mitamura (Trans. Jap. Path. Soc., *21*, 1931, 463) sums this up as follows: "Wir stellen

Hayashi, Jour. Parasit., 7, 1920, 63; **Rickettsia orientalis* Nagayo, Tamiya, Mitamura and Sato, Jikken Igaku Zasshi, *14*, May 20, 1930, 8 pp.; †*Rickettsia tsutsugamushi* Ogata, Cent. f. Bakt., I Abt., *122*, 1931, 249; *Rickettsia akamushi* Kawamura and Imagawa, *ibid.*, *122*, 1931, 258; *Rickettsia orientalis* var. *schüffneri* do Amaral and Monteiro, Mem. Inst. Butantan, 7, 1932, 360; *Rickettsia megawi* do Amaral and Monteiro, *idem; Rickettsia megawi* var. *fletcheri* do Amaral and Monteiro, *ibid.*, 361; *Rickettsia tsutsugamushi-orientalis* Kawamura, Nisshin Igaku, *23*, 1934, 000; *Rickettsia pseudotyphi* Vervoort, see Donatien and Lestoquard, Acta Conv. Tertii Trop. atque malariae morbis, pars I, 1938, 564; *Rickettsia sumatranus* (sic) Kouwenaar and Wolff, Proc. 6th Pacific Sci. Cong. (1939), *5*, 1942, 636; *Dermacentroxenus orientalis* Moshkovsky, Uspekhi Souremennoi Biologii (Russian) (Advances in modern biology), *19*, 1945, 13.) From two Japanese ideographs transliterated *tsutsuga*, something small and dangerous, and *mushi*, a creature now known to be a mite. If the *i* ending is accepted as forming a Latin genitive the modern meaning of the species name *tsutsugamushi*, would be 'of a dangerous mite'.

Small pleomorphic bacterium-like microorganisms, usually thicker than *Rickettsia prowazekii*, *Rickettsia typhi*, *Rickettsia rickettsii* and *Coxiella burnetii* and less sharply defined. Ellipsoidal or rod-shaped, often appearing as a diplococcus or as a short bacillus with bipolar staining resembling the plague bacillus. Diffusely distributed in the cytoplasm of the cell. Size 0.3 to 0.5 by 0.8 to 2

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nicht in Abrede dass Herr Hayashi bei einem kleinen Teil der von ihn beschriebenen Körperchen unsere *Rickettsia orientalis* vor sich gehabt hat". Hayashi vigorously defends his own observations in the same discussion and the following year after making comparative studies of strains of *Rickettsia orientalis* and his own *Rickettsia tsutsugamushi* reaches the following conclusion (*loc. cit.*) "*Rickettsia tsutsugamushi* and *Rickettsia orientalis* refer to one and the same species of microorganisms and there seems to be no way in which one can be recognized as differing from the other." Under these conditions the only valid name appears to be *Rickettsia tsutsugamushi*.—Editors.

* These authors publish practically the same preliminary paper in three other places as follows: Compt. rend. Soc. Biol., Paris, *104*, June 14, 1930, 637–641; Jap. Jour. Exper. Med., *8*, Aug. 20, 1930, 309–318 and Trans. Jap. Path. Soc., *20*, 1930, 556–566. The complete report on this work did not appear until the following year: Jap. Jour. Exper. Med., *9*, March 20, 1931, 87–150.—Editors.

† This binomial apparently first appears in the literature in a review article by Kawamura (Handbuch der path. Microorganismen, Kolle and Wassermann, 3 Aufl., *8*, 1930, 1398) where it is used incidentally and is attributed to Hayashi, 1923. The fact that Hayashi did not use *Rickettsia tsutsugamushi* before 1931 is confirmed by Mitamura (Trans. Jap. Path. Soc., *21*, 1931, 463) who states in a footnote: Kawamura und Ogata geben an, dass Hayashi 1923 für den Erreger den Namen *Rickettsia tsutsugamushi* vorgeschlagen hat. Eine solche Angabe Hayashi, is nicht nur uns, sondern auch dem Autor, wie er uns persönlich erzählt, unbekannt." Ogata apparently first used *Rickettsia tsutsugamushi* in the title of a paper that he presented in 1930 to the 8th Cong. Far East Assoc. Trop. Med. which, however, appeared in the Transactions of the Congress, *2*, June, 1932, 167–171. Meanwhile, the same paper with an added discussion of the nomenclature appeared in the Cent. f. Bakt., I Abt., Orig., *122*, Oct. 1, 1931, 249–253 and it is this paper that is usually regarded as establishing the use of *Rickettsia tsutsugamushi* for this species.—Editors.

microns. Non-motile. Colored purplish with the Giemsa stain, and red against a blue background with the Machiavello stain. Stains well with azur III and methylene blue. Gram-negative.

Cultivation: In plasma tissue culture of mammalian cells; on the chorio-allantoic membrane and in the yolk sac of the chick embryo; in rabbit testes and in the endothelial cells overlying Descemet's membrane of the rabbit eye.

Immunology: Immunity conferred by infection appears less complete than in typhus and Rocky Mountain spotted fever. Strains from several different areas have been found to cross immunize in guinea pigs, but the true relationship of the disease occurring in different localities remains to be determined. Reciprocal cross-immunity between mite strains and human strains has been demonstrated in rabbits, hamsters and mice.

Serology: Antigens from different strains vary in sensitivity when tested by complement fixation with immune sera. There are probably a number of different types on the basis of complement fixation with immune sera. Has a common antigenic factor with *Proteus* OX-K.

Resistance to chemical and physical agents: Readily inactivated by heat and chemical agents. Destroyed by a temperature of 50°C for 10 minutes, and by 0.1 per cent formalin and 0.5 per cent phenol.

Pathogenicity: Pathogenic for man, monkeys, gibbons, guinea pigs, hamsters, rats, voles, mice, gerbilles, rabbits (by intraocular injection) and chick embryo. There is wide variation in the virulence of different strains for laboratory animals, infection being established with great difficulty with some, while others may cause a high mortality.

A febrile reaction occurs in guinea pigs. Passage in guinea pigs and mice is accomplished by inoculation of infected spleen or blood from an infected animal, passage in rabbits by intraocular inoculation of blood, lymph node or organ emulsions of infected animals. Ascites, enlarged spleen often with a fibrinous deposit are characteristic.

In man an eschar with adenopathy develops at the site of the mite bite. In scrub typhus the eschar is not present. A febrile reaction with exanthema occurs and mortality is variable.

In rabbits infection of Descemet's membrane follows intraocular injection of infected material.

Source: Seen by Hayashi in smears and sections of the lesion (eschar) at the site of the mite bite and in smears and sections of the adjacent lymph nodes from cases of the disease; also seen by Nagayo et al. (*loc. cit.*) in the endothelial cells overlying Descemet's membrane in rabbits inoculated intraocularly with infectious material.

Habitat: The mites (*Trombicula akamushi*, *Trombicula deliensis* syn. *T. walchi*, *Trombicula fletcheri* and probably several others). Infective through the ova of the adult female. Only the larvae feed on rodents or man. Reservoir hosts are probably certain wild rodents, including house and field rats, mice and voles and probably some birds. The etiological agent of tsutsugamushi disease and scrub typhus (for numerous other designations of the disease see Farner and Katsampes, U. S. Naval Med. Bull., *43*, 1944, 800).

NOTE: *Rickettsia nipponica* Sellards. (Sellards, Amer. Jour. Trop. Med., *3*, 1923, 545; *Rickettsoides nipponica* da Rocha-Lima, in Kolle and Wasserman, Handb. d. path. Mikroorganismen, 3 Aufl., *8*, 1930, 1350.) This problematical organism was thought by its author to be the cause of tsutsugamushi disease. Because it was cultivatible by the methods used by Sellards, it is not now regarded as identical with *Rickettsia tsutsugamushi* Ogata. *Rickettsoides nipponica* is the type species (monotypy) of the

genus *Rickettsoides* da Rocha-Lima (*loc. cit.*).

6. **Rickettsia akari** Huebner, Jellison and Pomerantz. (Pub. Health Rept., *61*, 1946, 1682.) From *Acarus*, a genus of mites.

Minute diplobacilli, occurring intracellularly and extracellularly, and bipolarly stained rods. Resemble typical rickettsiae morphologically. Non-motile.

Stain well by Machiavello's method, the organisms appearing bright red against a blue background. Stain poorly with methylene blue. Gram-negative. Occur intracytoplasmically and have been seen intranuclearly in yolk sac cells.

Cultivation: In the yolk sac of the chick embryo. No growth on artificial culture media.

Immunology: Guinea pigs recovered from rickettsialpox are immune to infection with strains isolated from infected mites.

Serology: Antigens prepared from infected yolk sacs are highly specific except for cross reactions with Rocky Mountain spotted fever antigens. Sera from convalescent patients fixed complement with the homologous antigen and usually with Rocky Mountain spotted fever antigens though at a lower titer. Does not have a common antigenic factor with *Proteus* strains except that low titers were obtained in a few recovered cases in agglutination tests with *Proteus* OX19.

Pathogenicity: Pathogenic for man with focal initial erythematous lesion and adenopathy, followed by fever and appearance of macular rash. No mortality. Experimental infections have been produced in white mice and guinea pigs by the inoculation of infected blood (irregularly), and of infected liver and spleen suspensions, infected brain, infected lymph nodes, tunica washings of infected animals and by infected yolk sacs. Symptoms in mice include inactivity, accelerated respiration, ruffled fur, with occasional deaths; in guinea pigs, fever and marked scrotal reactions. Infected embryos are killed in 4 to 7 days. It has not been found pathogenic for monkeys, distinguishing it from *Rickettsia conorii*. It is also probably more pathogenic for white mice than *Rickettsia conorii*.

Source: Blood of a human case of rickettsialpox in New York City.

Habitat: Blood of human cases and an ectoparasite of rodents, the mite (*Allodermanyssus sanguineus* Hirst). The etiological agent of human rickettsialpox.

Genus II. **Coxiella** *Philip.*

(Subgenus *Coxiella* Philip, Amer. Jour. Hyg., *37*, 1943, 306; *Coxiella* Philip, Pub. Health Repts., U. S. P. H. S., *63*, Jan. 9, 1948, 58; not Bengtson, *gen. nov.* as stated in first printing Manual, 6th ed., Jan. 26, 1948, 1092.)

Small, pleomorphic, rod-shaped and coccoid organisms, occurring intracellularly in the cytoplasm and extracellularly in infected ticks. Stain lightly with aniline dyes. Gram-negative. They are filterable. Have not been cultivated in cell-free media. Parasites of man and animals which include the etiological agent of Q fever.

The type species is *Coxiella burnetii* (Derrick) Bengtson.

1. **Coxiella burnetii** (Derrick) Bengtson *comb. nov.* (*Rickettsia burneti* Derrick, Med. Jour. Australia, *1*, 1939, 14; *Rickettsia diaporica* Cox, Pub. Health Rep., *54*, 1939, 1826; *Rickettsia burneti* var. *americana*, Anon., Brit. Med. Jour., *2*, 1941, 588; *Rickettsia* (*Coxiella*) *burneti* Philip, Amer. Jour. Hyg., *37*, 1943, 306.) Named for F. M. Burnet who discovered the organism in Australia.

Small bacterium-like, pleomorphic organisms varying in size from coccoid forms to well marked rods. Occur as cytoplasmic micro-colonies with diffuse or compact distribution of the organisms through the cytoplasm. Also seen extracellularly, where they appear as small lanceolate rods, diplobacilli and occasionally segmented filamentous forms. Chains of 3 to 6 elements often seen. Quite uniform in size and morphology in infected yolk sacs and in mouse spleen with exceedingly minute forms in heavily infected material. Small lanceolate rods, 0.25 by 0.4 to 0.5 micron, bipolar forms 0.25 by 1.0 micron, diplobacilli 0.25 by 1.5 microns. Non-motile.

With Giemsa's stain they appear reddish-purple, with Machiavello's stain bright red against a blue background. Gram-negative.

Cultivation: May be cultivated in plasma tissue cultures, in modified Maitland media and in the yolk sac of chick embryos.

Immunology: There is complete cross immunity between Australian and American strains of Q fever in guinea pigs. Strains from other parts of the world also cross immunize.

Serology: American and Australian strains are identical by agglutination and agglutinin absorption. Strains from various countries are serologically related as shown by complement fixation. Q fever is distinguishable from other rickettsial diseases by complement fixation tests. No common antigenic factor with any *Proteus* strain has been demonstrated.

Filterability: The infectious agent of Q fever readily passes Berkefeld N filters which are impermeable to ordinary bacteria and W filters which are impermeable to typhus and spotted fever rickettsiae.

Resistance to chemical and physical agents: Comparatively resistant to heat, drying and chemical agents. Survives at least 109 days in cell-free media without loss of titer, resistant to 60°C for 1 hour and to 0.5 per cent formalin and 1 per cent phenol when tested in fertile eggs.

Pathogenicity: Pathogenic for man, guinea pig and the white mouse. The monkey, dog, white rat and rabbit are mildly susceptible. Certain bush animals in Australia, particularly the bandicoot, are susceptible and these animals have been found naturally infected. Other rodents and marsupials are mildly susceptible. Calves have been experimentally infected and cows have been found recovered from naturally acquired infections.

A febrile reaction occurs in guinea pigs but mortality is low except with heavily infected yolk sac which causes a high mortality. On subcutaneous or intradermal inoculation a marked inflammatory thickening of the skin occurs at the site of inoculation. On autopsy the spleen is enlarged from 2 to 12 times by weight and is engorged with blood. Transfer in guinea pigs and mice is accomplished by transfer of infected liver and spleen. A febrile reaction often accompanied by pneumonitis occurs in man, but mortality is low.

Source: First seen in smears from mice inoculated intraperitoneally with infectious material by Burnet and Freeman (Med. Jour. Australia, *2*, 1937 (2), 281).

Habitat: The wood tick (*Dermacentor andersoni*) and the ticks, *Dermacentor occidentalis*, *Amblyomma americanum*, *Haemaphysalis leporis-palustris*, *Ixodes dentatus* and *Haemaphysalis humerosa*. Several other species of ticks have been shown to transmit experimentally the virus of Q fever. It has been found to survive in the ova of the female ticks (*Dermacentor andersoni* and *Haemaphysalis humerosa*). The bandicoot (*Isodon macrurus*) is probably the natural reservoir of the disease in Australia. The etiological agent of Q (Queensland) fever in man.

Genus III. Cowdria *Bengtson, gen. nov.*

Named for E. V. Cowdry who first described the organism in heartwater of three ruminants, sheep, goats and cattle.

Small pleomorphic, spherical or ellipsoidal, occasionally rod-shaped organisms, occurring intracellularly in ticks. Gram-negative. Have not been cultivated in cell-free media. Parasites which are the etiological agent of heartwater of cattle, sheep and goats.

The type species is *Cowdria ruminantium* (Cowdry) Bengtson.

1. **Cowdria ruminantium** (Cowdry) Bengtson, *comb. nov.* (*Rickettsia ruminantium* Cowdry, Jour. Exp. Med., *42*, 1925, 231; *Rickettsia* (*Cowdria*) *ruminantium* Moshkovsky, Uspekhi Souremennoi Biologii (Russian) (Advances in Modern Biology), *19*, 1945, 18.) From M. L. *Ruminantia*, the cud-chewing mammals.

Differ morphologically from typical rickettsiae, showing usually spherical and ellipsoidal forms; occasionally bacillary forms. Irregular pleomorphic forms occur. Grow in the cytoplasm of cells, sometimes in densely packed masses. Size of cocci from 0.2 to 0.5 micron in diameter in the endothelial cells of animals, 0.2 to 0.3 micron in diameter in ticks. Bacillary forms 0.2 to 0.3 by 0.4 to 0.5 micron and pairs 0.2 by 0.8 micron in ticks. Non-motile.

Stain blue with the Giemsa stain and can also be stained by methylene blue and other basic aniline dyes. Gram-negative.

Cultivation not reported.

Immunology: Immunity incomplete after recovery from the infection. The organisms are found in the tissues long after recovery. There is some evidence of a variety of strains.

Pathogenicity: Pathogenic for goats, sheep and cattle. Transmissible to goats by inoculation of infected blood intrajugularly. The most characteristic lesion is the hydropericardium of infected animals. The only small animal shown to be susceptible is the ferret.

Source: Seen in the endothelial cells of renal glomeruli and in the endothelial cells of the cerebral cortex of animals suffering from heartwater and in the tick, *Amblyomma hebraeum*.

Habitat: The bont tick (*Amblyomma hebraeum*) and also *Amblyomma variegatum*. When the tick is infected in the larval state, it can transmit the infection to the nymphal and adult stages, but the disease is not transmissible through the ova of the adult female tick. The etiological agent of heartwater in sheep, goats and cattle in South Africa.

Appendix I: Further studies of the organism of trench fever are required before the relationship of *Rickettsia quintana* to the other more firmly established species of rickettsiae can be determined. Therefore, it is placed in this appendix.

1. *Rickettsia quintana* Schminke. (Schminke, Münch. med. Wchnschr., *64*, July 17, 1917, 961; *Rickettsia wolhynica* Jungmann and Kuczynski, Ztschr. klin. Med., *85*, 1918, 261; *Fossilis quintana* suggested as a possible subspecies "if necessary" by Megaw, Trop. Dis. Bull., *40*, 1943, 828.)

Probable synonym: *Rickettsia pediculi* Munk and da Rocha-Lima, Münch. med. Wchnschr., *64*, 1917, 1423.

Coccoid or ellipsoidal organisms, often occurring in pairs, more plump and staining more deeply with the Giemsa stain than *Rickettsia prowazekii*. Da Rocha-Lima gives their size as 0.2 to 0.4 micron by 0.3 to 0.5 micron. In lice appear as short rods, frequently in pairs and often bipolarly stained. Non-motile.

Stain reddish-violet with the Giemsa stain. Gram-negative. Occur extra-

cellularly in the region of the epithelial lining of the gut of the louse.

Cultivation: Has not been cultivated in tissue culture or any cell-free medium, though *Rickettsia pediculi*, considered by some identical with *Rickettsia quintana*, has been cultivated on human and horse blood agar.

Pathogenicity: Pathogenic for man, causing recurrent fever. No strain has been definitely established in laboratory animals.

Immunology: Partial immunity is produced after an attack of the disease. The disease is characterized by relapses which may occur as long as two years after the initial attack.

Distinctive characteristics: The organism resists a temperature of 60°C moist heat for 30 minutes or a dry heat at 80°C for 20 minutes. It resists desiccation in sunlight for 4 months. It is filterable under certain conditions but not when in plasma or serum. It is present in filtrates of infected vaccine sediments and excrements of infected lice.

Source: Seen in lice fed on trench fever patients by Töpfer (Münch. med. Wchnschr., *61*, 1916, 1495).

Habitat: The epithelial lining of the gut of the body louse (*Pediculus humanus* var. *corporis*) where they occur extracellularly, and *Pediculus capitis*. The virus is not transmissible through the ova. May be the etiological agent of trench fever (Wolhynian fever, shin bone fever, five-day fever).

Appendix II: Additional named species are included in Chapter V, *Rickettsiae*, in Steinhaus, Insect Microbiology. Ithaca, 1946, 304–328. Some differ morphologically and tinctorially from typical rickettsiae, some are not associated with an arthropod vector, some have been incompletely studied and described, some have been cultivated in cell-free media. Pending the completion of further studies involving possible cultivation in fertile eggs, the determination of biological properties, and adequate comparative immunological and serological studies, no attempt is made to classify these organisms. The descriptions are condensed from those given by Steinhaus:

Ehrlichia (*Rickettsia*) *kurlovi* Moshkovsky. (Compt. rend. Soc. Biol., Paris, *126*, 1937, 379; *Ehrlichia kurlovi* Moshkovsky, Uspekhi Souremennoi Biologii (Russian) (Advances in Modern Biology), *19*, 1945, 12.) Found in the monocytes of guinea pigs. Described by Kurloff in 1889 as inclusions in the mononuclear cells of guinea pigs and other animals. These became known as Kurloff bodies. However, the parasitism of these bodies is questionable.

Rickettsia avium Carpano. (Riv. Pat. Comp., Jan.–Feb., 1936, 1.) Minute bodies in the leucocytes and tissue cells of a bullfinch (*Pyrrhula europea*) brought to Egypt from Germany. Donatien and Lestoquard (Arch. Inst. Pasteur Algérie, *15*, 1937, 142) suggested that this organism might have been that of psittacosis.

Rickettsia bovis Donatien and Lestoquard. (Donatien and Lestoquard, Bull. Soc. Path. Exot., *29*, 1936, 1057; *Ehrlichia bovis* Moshkovsky, Uspekhi Souremennoi Biologii (Russian) (Advances in Modern Biology), *19*, 1945, 18.) Concerned in a disease of cattle which is transmitted by an unidentified tick of the genus *Hyalomma*. The organism occurs in circular or round-angled polygonal masses which consist of a large number of tightly pressed, minute spherical granulations. These masses are situated in the cytoplasm of various monocytes. The organism causes a relatively light febrile disease in cattle, and an inapparent infection in sheep and fever in monkeys.

Rickettsia canis Donatien and Lestoquard. (Donatien and Lestoquard, Bull. Soc. Path. Exot., *28*, 1935, 418; *Ehrlichia* (*Rickettsia*) *canis* Moshkovsky, Compt.

rend. Soc. Biol., Paris, *126*, 1937, 382; *Ehrlichia canis* Moshkovsky, Uspekhi Souremennoi Biologii (Russian) (Advances in Modern Biology), *19*, 1945, 18.) Moshkovsky selects this species as the type species of the subgenus *Ehrlichia* Moshkovsky (*loc. cit.*). Found in dogs used for experimental purposes in Algeria. Appears to be transmitted naturally by the dog tick (*Rhipicephalus sanguineus*). All active stages of the tick transmit the organism and it passes intraovarially from the female to the larvae of the next generation. The organisms are generally spherical in shape and can be seen in the circulating monocytes. The infection causes a serious and often fatal illness in dogs. Small laboratory animals are not susceptible to the disease.

Rickettsia conjunctivae, *Rickettsia conjunctivae bovis* and *Rickettsia conjunctivae galli*, see Family III, *Chlamydozoaceae*.

Rickettsia ctenocephali Sikora. (Arch. Schiffs- u. Tropenhyg., *22*, 1918, 442.) Found in cat fleas (presumably *Ctenocephalides felis*) on the surface of the organs in the body cavity and in the coelomic fluid. Two forms were found which might be two species, one resembling *Rickettsia pediculi* and the other *Rickettsia melophagi*. Hertig and Wolbach (Jour. Med. Res., *44*, 1924, 329) found *Rickettsia ctenocephali* to vary in size and shape from minute cocci to rather large, swollen, curved rods, staining reddish with the Giemsa stain.

Rickettsia culicis Brumpt. (Ann. Parasitol. Hum. et Comp., *16*, 1938, 153.) Found in the stomach epithelium of mosquitoes (*Culex fatigans*) 12 days after they had been fed on a patient carrying *Microfilaria bancrofti*. Thought to be pathogenic for the mosquito and possibly for man. Occurs in the form of small granules and more often as small bipolar rods. Stains with haemalum, erythrosine-orange and toluidine blue. Gram-negative.

Rickettsia dermacentrophila Steinhaus. (Pub. Health Repts., *57*, 1942, 1375.) Found in all stages of the wood tick (*Dermacentor andersoni*). In the epithelial cells of the intestinal diverticula and other tissues of the tick, usually extracellularly but sometimes intracellularly. Not seen in the nuclei of cells. Gram-negative and staining red with the Machiavello stain, and bluish-purple with the Giemsa stain. Stains less deeply with ordinary bacterial stains than most bacteria. Resembles *Rickettsia rickettsii* morphologically but is slightly larger. Not pathogenic for laboratory animals or for some of the natural hosts of *Dermacentor andersoni*.

Rickettsia hirundinis Cowdry. (Jour. Exp. Med., *37*, 1923, 431.) An organism observed by Arkwright, Atkin and Bacot (Parasitology, *13*, 1921, 27) in the tissues of *Cimex hirundinis* which is probably the same organism to which Cowdry referred as *Rickettsia hirundinis*. Considered by Steinhaus as a *nomen nudum*.

Rickettsia kairo da Rocha-Lima. (Cairo rickettsia, Arkwright and Bacot, Brit. Jour. Exper. Path., *4*, 1923, 70; da Rocha-Lima, in Kolle and Wasserman, Handb. d. path. Mikroorg., 3 Aufl., *8*, 1930, 1361.) Resembles *Rickettsia rochalimae* and *Rickettsia prowazekii*.

Rickettsia lectularia Arkwright, Atkin and Bacot. (Parasitology, *13*, 1921, 27.) Found in the gut of the bedbug (*Cimex lectularius*) as filamentous and rod-shaped organisms. It seems probable that all bedbugs harbor the organism and it is also present in the developing ova. The location is intracellular. Very pleomorphic, ranging from small coccoid forms to thread-like forms. The small coccoid and diplococcoid forms stain deep purple with the Giemsa stain, while bacillary, lanceolate and thread forms stain more red than purple with the Giemsa stain. Not infective for small laboratory animals or for man.

Rickettsia linognathi Hindle. (Parasitology, *13*, 1921, 152.) Found in the

alimentary tract of the goat louse (*Linognathus stenopsis*). Resembles *Rickettsia trichodectae* morphologically and occurs only extracellularly in the lumen of the gut.

Rickettsia melophagi Nöller. (Arch. Schiffs- u. Tropenhyg., *21*, 1917, 53.) Found upon and in the cuticular layer covering the epithelium of the midintestine of the sheep tick (*Melophagus ovinus*). Occurs characteristically in pairs of fairly uniform size, coccoid and sometimes rod-shaped. Gram-negative but stains fairly well with carbol-fuchsin and gentian violet. Stains deep purple with Giemsa's method and bright red with Machiavello's method. Has been cultivated on non-living culture media, a glucose-blood-bouillon agar medium. The ability of *Rickettsia melophagi* to infect sheep has been the subject of contradictory claims. Small laboratory animals seem not to be susceptible.

Rickettsia ovina Lestoquard and Donatien. (Lestoquard and Donatien, Bull. Soc. Path. Exot., *29*, 1936, 108; *Ehrlichia ovina* Moshkovsky, Usphekhi Souremennoi Biologii (Russian) (Advances in Modern Biology), *19*, 1945, 18.) Found in the blood of diseased sheep from Turkey and Algeria. The organisms occur as minute coccoid granules, grouped in masses and present only in the monocytes and never in endothelial cells. They stain uniformly dark red with the Giemsa stain but did not stain with the Castañeda technic. Infected ticks (*Rhipicephalus bursa*) are thought to be the vectors.

Rickettsia pisces Mohamed. (Ministry Agr., Egypt., Tech. Sci. Serv. Bull. 214, 1939, 6 pp.) In the monocytes and plasma of the blood of a fish (*Tetraodon fahaka*) showing necrotic ulcers on its head and both sides of the body. The heart, liver and intestines showed lesions. The organisms were minute coccoid forms varying from 0.2 to 0.4 micron in diameter and frequently occurring in pairs.

Rickettsia rocha-limae Weigl. (Przglad. Epidemj., *1*, 1921, 375.) Occurs in lice (*Pediculus humanus*) but is apparently non-pathogenic either to lice or to vertebrates. Larger and more pleomorphic than *Rickettsia prowazekii*. In smears or sections of the gut of lice, *Rickettsia rocha-limae* occurs in agglomerated masses, grouped like staphylococci. They occur both extracellularly and intracellularly and stain more deeply than *Rickettsia prowazekii*. Weigl claims to have cultivated this species on artificial culture media under anaerobic conditions. Not pathogenic for laboratory animals or man.

Rickettsia suis Donatien and Gayot. (Bull. Soc. Path. Exot., *35*, 1942, 324.) Causes a disease in swine, the pathology of which resembles heartwater of ruminants. See Genus III, *Cowdria*, Family *Rickettsiaceae*.

Rickettsia trichodectae Hindle. (Parasitology, *13*, 1921, 152.) In the species of biting lice (*Trichodectas pilosus*) which may be found on horses. This insect does not suck blood. The organisms occur extracellularly in the alimentary tract of the louse. The average size is 0.3 to 0.5 by 0.5 to 0.9 micron and occasionally longer forms occur.

Rickettsia weigli Mosing. (Arch. Inst. Pasteur, Tunis, *25*, 1936, 373.) Concerned in an epidemic disease which broke out in 1934 among employees of the Institute of Biology in Lwów who were engaged in feeding supposedly uninfected lice on their persons. Mosing and others have suggested the possibility that this rickettsia may be an extreme mutant of *Rickettsia pediculi*. Small coccoid to rod-shaped organisms staining well with the Giemsa stain, usually slightly longer than *Rickettsia prowazekii*. In the louse (*Pediculus humanus*), the rickettsiae occur extracellularly in the intestinal lumen forming a layer covering the surface of the epithelial lining. Not pathogenic for the louse as is *Rickettsia prowazekii* and *Rickettsia*

rocha-limae. It causes a febrile illness in man in which relapses occurred 3 to 5 times as in trench fever. *Rickettsia weigli* was agglutinated by convalescent sera but not by sera from typhus patients. Convalescent sera gave no positive Weil-Felix reaction.

Wolbachia pipientis Hertig. (Rickettsia of *Culex pipiens*, Hertig and Wolbach, Jour. Med. Res., *44*, 1924, 329; Hertig, Parasitology, *28*, 1936, 453.) This is the type species of the genus *Wolbachia* Hertig (*loc. cit*). Found in the ovaries or testes of the mosquito, and present in all stages o the mosquito's development. The outstanding morphological characteristic of the organism is great pleomorphism. Minute coccoids and short rods may be considered typical, but the usual microscopic field consists of various shapes and sizes. Some forms show bipolar staining with the Giemsa stain. The organism is a harmless parasite of the mosquito. Laboratory animals are apparently not susceptible.

The following unnamed rickettsiae isolated from animals or seen in animals are included in Steinhaus' list of rickettsiae (Insect Microbiology. Ithaca, 1946, 344):

A rickettsia was isolated by Parker, Kohls, Cox and Davis (Pub. Health Rept., *54*, 1939, 1482) from a tick (*Amblyomma maculatum*). It is pathogenic for guinea pigs and the disease is referred to as the maculatum disease. There is complete cross immunity in guinea pigs between this infection and Rocky Mountain spotted fever and boutonneuse fever, but it differs from these diseases in some particulars.

A rickettsia-like organism was isolated from the reduviid bug (*Triatoma rubrofasciata*) by Webb (Parasitology, *32*, 1940, 355). It was pathogenic for some laboratory animals and was maintained in guinea pigs for 5 passages. The rickettsiae were transmissible to the next generation through the egg of the reduviid bug.

A spotted fever type of rickettsia was isolated by Anigstein and Bader (Texas Repts. Biol. Med., *1*, 1943, 105) from the dog tick (*Rhipicephalus sanguineus*) taken from normal dogs. It was pathogenic for rabbits and guinea pigs.

A rickettsia was isolated by Anigstein and Bader (Texas Repts. Biol. Med., *1*, 1943, 298, 389) from ticks (*Amblyomma americanum*) collected in Texas. They believed it to be the cause of bullis fever.

Rickettsiae were observed by Enigh (Berl. u. Münch. Tierärztl. Wchnschr., 1942, 25) in the leucocytes of a bison calf. No arthropod was associated with this rickettsia.

A rickettsia-like agent pathogenic for guinea pigs was reported by Tatlock (Proc. Soc. Exp. Biol. and Med., *57*, 1944, 95). The animals had been injected with blood from a patient with "pretibial" fever. No arthropod vector was indicated.

Three species of rickettsia-like organisms isolated from the wood-tick (*Dermacentor andersoni*) are described by Noguchi (Jour. Exper. Med., *43*, 1926, 518–521). These were named *Bacillus rickettsiformis*, *Bacillus pseudoxerosis* and *Bacillus equidistans*. All could be cultivated on cell-free media and none was pathogenic for laboratory animals.

Appendix III: Unnamed rickettsia-like organisms seen in the tissues of insects.

Hertig and Wolbach (Jour. Med. Res., *44*, 1924, 329) list sixteen species of arachnids and twenty-three species of insects which are hosts to rickettsiae or rickettsia-like organisms.

Wolbach (Jour. Amer. Med. Assoc., *84*, 1925, 723) reports hosts of non-pathogenic rickettsiae which include fourteen species of arachnids (ticks, mites and spiders) and twenty-two species of insects distributed in nine orders, including

numerous non-blood-sucking insects as well as lice and ticks.

Cowdry (Arch. Path. and Lab. Med., *2*, 1926, 59) lists seven species of arachnids and twenty-four species of insects which are hosts to non-pathogenic rickettsiae.

Buchner, P. (Tier und Pflanze in Symbiose. Gebrüder Borntraeger, Berlin, 1930, 900 pp.) Through the text, and particularly on pages 300–664, the rickettsia-like and bacterium-like microorganisms occurring intracellularly in insects and other small animals are discussed, principally from the viewpoint of the biologist.

Paillot, A. (L'infection chez les Insects, Paris, 1933, 535 pp.). Concerned principally with bacterial infections of insects, but also includes information in intracellular symbiotes and rickettsia-like and bacterium-like microorganisms.

Steinhaus, Edward A. (Insect microbiology. Ithaca, 1946, 188–255.) Intracellular bacterium-like and rickettsia-like symbiotes are discussed.

FAMILY II. BARTONELLACEAE GIESZCZYKIEWICZ.*

(Bull. Intern. Acad. Polon. Sci., Classe Sci. Math. Nat., B (I), 1939, 9–30.)**

Small, often pleomorphic, rod-shaped, coccoid, ring-shaped, filamentous and beaded micro-organisms, staining lightly with aniline dyes, but well with Giemsa's stain. Gram-negative. Parasites of the erythrocytes in man and other vertebrates. Known to be transmitted by arthropod vectors in some cases. The causative organisms of bartonellosis in man, haemobartonellosis, grahamellosis and eperythrozoönosis in the lower animals. Differ from the protozoa that also parasitize erythrocytes in that the entire parasite stains with no differentiation into cytoplasm and nucleus.

Key to the genera of family **Bartonellaceae.**

1. Parasites of the erythrocytes and of fixed tissue in man.
   Genus I. *Bartonella*, p. 1100.
2. Parasites of the erythrocytes of lower mammals, increased in susceptible animals by splenectomy. Eradicated by arsenicals.
   Genus II. *Haemobartonella*, p. 1102.
3. Parasites of the erythrocytes of lower mammals. Not increased in susceptible animals by splenectomy. Not eradicated by arsenicals.
   Genus III. *Grahamella*, p. 1109.
4. Blood parasites, found on the erythrocytes and in the plasma of lower mammals. Appear as rings, coccoids and short rods. Splenectomy activates latent infections.
   Genus IV. *Eperythrozoon*, p. 1111.

Genus I. **Bartonella** *Strong, Tyzzer and Sellards.*

(*Bartonia* Strong, Tyzzer, Brues, Sellards and Gastiaburú, Jour. Amer. Med. Assoc., *61*, 1913, 1715; not *Bartonia* Muhlenberg, in Willdenow, Neue Schrift Ges. Nat. Fr., Berlin, *3*, 1801, 444; not *Bartonia* Sims, Bot. Mag., 1804; not *Bartonia* Crossman, Essais de Paleoconchologie Comparée, 4me Livr., Paris, 1901; Strong, Tyzzer and Sellards, Jour. Amer. Med. Assoc., *64*, 1915, 808; *emend.* Tyzzer and Weinman, Amer. Jour. Hyg., *30* B, 1939, 143.) Named for A. L. Barton who described these organisms in 1909.

Parasites of the erythrocytes which also multiply in fixed tissue cells. On the red blood cells in stained films, they appear as rounded or oval forms or as slender, straight, curved or bent rods occurring either singly or in groups. Characteristically in chains of several segmenting organisms, sometimes swollen at one or both ends and

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* Prepared by Dr. Ida A. Bengtson (retired), National Institute of Health, Bethesda, Maryland and Dr. David Weinman, Parasitologist to the 1937 Harvard Expedition to Peru, Boston, Mass., April, 1947.

** Partial syn. *Anaplasmidae* has been proposed as a family name to unite the four genera *Anaplasma, Grahamella, Bartonella* and *Eperythrozoon* by Neitz, Alexander and du Toit (Onderst. Jour. Vet. Sci. and An. Ind., *3*, 1934, 268). Since the name is derived from *Anaplasma*, the nature of which is not fully understood and since these authors consider the 4 genera as belonging to the protozoan order *Haemosporidia*, it seems advisable not to consider this nomenclature for the present. The genus *Anaplasma* (parasites of the red blood cells of cattle) created by Theiler (Transvaal Govt. Vet. Bact. Rept. 1908–9, 7–64, 1910) consists of two species *Anaplasma marginale* and *Anaplasma centrale*. Recent workers are inclined to consider them to be bacterial in nature as they do not show a differentiation into cytoplasm and nucleus.

frequently beaded (Strong et al., *loc. cit.*, 1913), without a distinct differentiation of nucleus and cytoplasm. In the tissues they are situated within the cytoplasm of endothelial cells as isolated elements and grouped in rounded masses. These parasites occur spontaneously in man and in arthropod vectors, are endowed with independent motility, reproduce by binary fission, and may be cultivated by unlimited serial transfers on cell-free media. One species has been recognized. It is known to be established only on the South American continent and perhaps in Central America. Human bartonellosis may be manifested clinically by one of the two syndromes constituting Carrión's disease (Oroya fever or verruga peruana) or as an asymptomatic infection (definition by Strong, Tyzzer and Sellards *emend.* Tyzzer and Weinman (in Weinman, Trans. Amer. Philosoph. Soc., N.S., *33*, pt. 3, 1944, 246).

The type species is *Bartonella bacilliformis* (Strong et al.) Strong et al.

1. **Bartonella bacilliformis** (Strong, Tyzzer, Brues, Sellards and Gastiaburú) Strong, Tyzzer and Sellards. (*Bartonia bacilliformis* Strong et al., Jour. Amer. Med. Assoc., *61*, 1913, 1715; *Bartonella bacilliformis* Strong, Tyzzer and Sellards, Jour. Amer. Med. Assoc., *64*, 1915, 808; *emend.* Tyzzer and Weinman, Amer. Jour. Hyg. *30*(B), 1939, 143; also see Weinman, Trans. Amer. Philosoph. Soc., N.S., *33*, pt. 3, 1944, 246. Partial or complete synonyms: *Bartonella cocoide* (sic) Hercelles, Ann. de Fac. de Med., Lima, *9*, 1926, 231; *Bartonella peruviana* Escomel, Bull. Soc. path. Exot., *22*, 1929, 354; *Eperthyrozoon noguchii* Lwoff and Vaucel, Compt. rend. Soc. Biol., Paris, *103*, 1930, 975.) From Latin *bacillus*, rod and *forma*, shape.

Small, pleomorphic organisms, showing greatest morphological range in the blood of man, appearing as red-violet rods or coccoids situated on the red cells, when stained with Giemsa's stain. Bacilliform bodies are the most typical, measuring 0.25 to 0.5 by 1 to 3 microns. Often curved and may show polar enlargement and granules at one or both ends. Rounded organisms measure about 0.75 micron in diameter and a ring-like variety is sometimes abundant. On semi-solid media a mixture of rods and granules appear. The organisms may occur singly or in large and small, irregular dense collections, measuring up to 25 microns or more in length. Punctiform, spindle-shaped and ellipsoial forms of the organism occur, varying in size from 0.2 to 0.5 by 0.3 to 3 microns.

Gram-negative and non-acid-fast. Stain poorly or not at all with the usual aniline dye stains, but satisfactorily with Romanowsky and Giemsa stains.

Motile in the blood and in cultures. One to four unipolar flagella.

Cultivation: Growth in semi-solid agar with fresh rabbit serum and rabbit hemoglobin and in semi-solid agar with blood of man, horse or rabbit with or without the addition of fresh tissue and certain carbohydrates, in other culture media containing blood, serum or plasma, Huntoon's hormone agar at 20 per cent, semi-solid gelatin media, blood-glucose-cystine agar, chorio-allantoic fluid and yolk sac of chick embryo.

Gelatin not liquefied.

No acid or gas in glucose, sucrose, galactose, maltose, fructose, xylose, lactose, mannose, mannitol, dulcitol, arabinose, raffinose, rhamnose, dextrin, inulin, salicin and amygdalin.

No action on lead acetate.

Aerobic, obligate.

Optimum temperature 28°C.

Immunology: Natural immunity to infection has not been demonstrated in susceptible species. Acquired immunity apparent both during and after the disease. Bartonellae from different sources appear to provoke similar responses. Bartonellae from Oroya fever protect

against infection with organisms obtained from verruga cases.

Serology: Immune sera fix complement and agglutination of suspensions of *Bartonella* by sera from recovered cases has been reported.

Pathogenicity: Three forms of the disease occur in man; the anemic (Oroya fever), the eruptive (verruga peruana) and mixed types of both of the other forms. Experimental Oroya fever has not been successfully produced in animals, except rarely in an atypical form in monkeys. Experimental verruga peruana has been produced in man, in a number of species of monkeys and occasionally in dogs.

Source: Blood and endothelial cells of lymph glands, spleen and liver of human cases of Oroya fever.

Habitat: Blood and endothelial cells of infected man, probably also in sand flies (*Phlebotomus verrucarum* and *Phlebotomus noguchii*).

Genus II. **Haemobartonella** *Tyzzer and Weinman.*

(Amer. Jour. Hyg., *30*(B), 1939, 141.) From Greek *haemos*, blood and the generic name *Bartonella*.

Includes parasites of the red blood cells in which there is no demonstrable multiplication in the tissues and which do not produce cutaneous eruptions. They are typically rod- or coccoid-shaped, showing no differentiation into nucleus and cytoplasm, occurring naturally as parasites of vertebrates, and are transmitted by arthropods. They are distributed over the surface of the erythrocytes, and possibly sometimes within them. They stain well with Romanowsky type stains and poorly with other aniline dyes. Gram-negative. Not cultivated indefinitely in cell-free material. Rarely produce disease in animals without splenectomy, are markedly influenced by arsenotherapy, and are almost all of world-wide distribution. The experimental host range is restricted, infectivity of a rodent species for other rodents being common, but for primates unknown.

The type species is *Haemobartonella muris* (Mayer) Tyzzer and Weinman.

Key to the species of genus **Haemobartonella.**

I. The etiological agent of haemobartonellosis of the white rat.
   1. *Haemobartonella muris.*

II. The etiological agent of haemobartonellosis of the dog.
   2. *Haemobartonella canis.*

III. The etiological agent of haemobartonellosis of the vole.
   3. *Haemobartonella microtii.*

IV. The etiological agent of haemobartonellosis of the guinea pig.
   4. *Haemobartonella tyzzeri.*

V. The etiological agent of haemobartonellosis of cattle.
   5. *Haemobartonella bovis.*

VI. The etiological agent of haemobartonellosis of the buffalo.
   6. *Haemobartonella sturmanii.*

VII. The etiological agent of haemobartonellosis of the deer mouse.
   7. *Haemobartonella peromyscii.*

VIII. The etiological agent of haemobartonellosis of the gray-backed deer mouse.
   7a. *Haemobartonella peromyscii var. maniculati.*

IX. The etiological agent of haemobartonellosis of the short-tailed shrew.
   8. *Haemobartonella blarinae.*

X. The etiological agent of haemobartonellosis of the gray squirrel.
   9. *Haemobartonella sciurii.*

1. **Haemobartonella muris** (Mayer) Tyzzer and Weinman. (*Bartonella muris* Mayer, Arch. f. Schiffs.- u. Tropenhyg., *25*, 1921, 151; *Bartonella muris ratti* Regendanz and Kikuth, Compt. rend. Soc. Biol., Paris, *98*, 1928, 1578; Tyzzer and Weinman, Amer. Jour. Hyg., *30*(B), 1939, 143.) From Latin *mus*, *muris*, mouse.

Slender rods with rounded ends, frequently showing granules or swellings at one or both extremities, and dumbbell, coccoid or diplococcoid forms. May occur individually, in pairs, or in short chains of 3 or 4 elements, and, when abundant, in parallel grouping. The rods measure 0.1 by 0.7 to 1.3 microns and as much as half the length of a red cell. The coccoids have a diameter of 0.1 to 0.2 micron.

They have been found on and in the erythrocytes and in the plasma. Preferred stains are those of the Romanowsky type. With Giemsa's stain various investigators report an intense red coloration, a bluish tinge with distinct pink shading, blue with purple granules. With Wright's stain, the organisms stain bluish, with reddish granules at the ends. With Schilling's methylene blue-eosin stain the organisms stain a bright red color with the erythrocyte staining blue. They stain faintly with Manson's stain, pyronin-methyl green and fuchsin. Gram-negative.

There is lack of agreement concerning visibility in the fresh state and motility. Various authors report Brownian movement, slow and sinuous motion in the red cell or rapid motion.

Cultivation: Cultivated with difficulty and divergent results have been reported. Growth on various media reported (blood agar, agar with 2 per cent defibrinated rat blood, horse blood agar, N. N. N., Blutrösplatte of Wethmar, hormone agar with blood of rabbit, horse or man, ascitic fluid agar, chocolate agar, semi-solid rabbit serum agar, semi-solid rabbit blood agar, Noguchi-Wenyon medium, defibrinated rat blood, glucose broth, Tarozzi broth, peptone water) but usually growth was scant or could not be continued by transfer to the same medium or the organism isolated was non-infectious or the possibility of latent infections in the animal was not excluded. Best results are apparently obtained with semi-solid rabbit serum agar and semi-solid rabbit blood agar.

No conclusive results have been reported in tissue culture. The organism has been cultivated on the chorio-allantoic membrane of the chick embryo.

Filterability: Non-filterable with Seitz or Berkefeld N filters.

Immunology: No authentic case of true natural immunity in rats has been established. Acquired immunity occurs in (1) the latently-infected rat, (2) the infected rat after splenectomy and recovery from the disease, the period of resistance corresponding to the duration of latency, (3) the non-splenectomized non-carrier rat following infection, (4) animals other than the rat following infection.

Serology: No precipitins, thrombocytobarin, isoagglutinins, or cold hemolysins have been reported in the serum of anemic rats. Complement deviation and agglutination have been reported with sera from rabbits, rats and guinea pigs injected with cultures. Rabbits immunized with cultures have given positive Weil-Felix reactions with *Proteus* OX19 and OXK and rat sera recovered from haemobartonellosis have given a positive Weil-Felix reaction and positive agglutination in low dilution with *Rickettsia prowazekii*.

Pathogenicity: Infected blood, liver suspension, defibrinated laked blood, washed red cells, plasma and hemoglobinuric urine may produce infection by the subcutaneous, intravenous, intraperitoneal or intracardiac routes. Slight, transient or no haemobartonellosis occurs in adult non-splenectomized haemobartonella-free albino rats, adult non-splenectomized albino rats of carrier stock, adult splenectomized rats pre-

viously infected, until 15 weeks to 8 months after infection. Typical haemobartonellosis occurs in adult splenectomized haemobartonella-free albino rats and in young non-splenectomized haemobartonella-free albino rats weighing 20 to 30 grams at 3 weeks. Variable results have been obtained by different investigators with wild mice, guinea pigs, rabbits, hamsters, pigeons and monkeys (*Macacus rhesus* and *Macacus sp.*). It is known to be infectious for wild rats, albino mice, rabbits and for two Palestinian rodents (*Sphallax* (*Spalax* correct designation) *typhlops* and *Meriones tristrami*). Negative results have been reported in dogs, kittens, cats, sheep and various birds. Causes a definite and characteristic anemia without cutaneous eruption.

Arsenical therapy: True sterilization of latent or recognized infection with organic arsenical compounds.

Source: Blood of infected albino rats.

Habitat: Ectoparasites such as the rat louse (*Polyplax* (*Haematopinus*) *spinulosus*), the flea (*Xenopsylla cheopis*) and possibly the bedbug (*Cimex lectularius*). Also found in the erythrocytes of susceptible animals. World wide in distribution.

2. **Haemobartonella canis** (Kikuth) Tyzzer and Weinman. (*Bartonella canis* Kikuth, Klin. Wchnschr., 1928, 1729; Tyzzer and Weinman, Amer. Jour. Hyg., *30*(B), 1939, 151.) From Latin *canis*, dog.

One of the most pleomorphic of the haemobartonellae, occurring as thin rods, straight or slightly curved, dumbbell-shaped organisms, dots, coccoids, or rings. Chains of rods, coccoids or rings occur. These consist of only one type of these forms or a mixture of types. The chains may be straight, curved, branched or annular. Variable in size. Round forms vary from 0.2 or 0.5 micron to the limit of visibility. Single rods are 0.2 by 1 to 5 microns, while the composite forms vary from 1 to 4 microns. Situation is epi-erythrocytic.

Giemsa's fluid stains the organism red-violet, usually intensely. Methylene blue used as a vital stain colors the organism distinctly. Gram-negative and non-acid-fast.

Considered non-motile by most investigators.

Cultivation: Cultivation has not been demonstrated in semi-solid rabbit serum-agar medium nor in media containing serum of splenectomized dogs, N.N.N., Noguchi's medium for leptospira, blood broth, Chatton's medium covered with vaseline for *Trichomastix*.

Filterability: Results equivocal.

Immunology: The outstanding phenomena resemble those found in the rat infected with *Haemobartonella muris*.

Pathogenicity: Splenectomy is essential to infection accompanied by anemia in the dog. Negative results in splenectomized haemobartonella-free guinea pig, rat, rabbit, and monkey (*Cercopithecus sabaeus*). No infection or anemia in unoperated mice, white rats, young rabbits, young dogs and young guinea pigs. The splenectomized cat has been found to carry the infection by serial passage.

Arsenical therapy: Complete sterilization obtained by neoarsphenamine.

Source: Erythrocytes of infected splenectomized dogs.

Habitat: Found in dog fleas (*Ctenocephalus*) and erythocytes of infected animals. Distribution wide-spread, the infection occurring spontaneously in Europe, India, North and South Africa, North and South America.

3. **Haemobartonella microtii** Tyzzer and Weinman. (Tyzzer and Weinman, Amer. Jour. Hyg., *30*(B), 1939, 143; also see Weinman, Trans. Amer. Philosoph. Soc., N. S., *33*, 1944, 312; questionable synonym *Bartonella arvicolae* Yakimoff, Arch. Inst. Past. de Tunis, *17*, 1928, 350; *Haemobartonella arvicolae* Weinman, *loc.*

cit., 290.) From the genus of voles, *Microtus*.

In infected animal, morphology resembles that of *Haemobartonella canis*, the organisms occurring as rods, coccoids, filaments, club forms, ring forms and granular masses. In addition to these forms there occur in Giemsa-stained blood films ovoids, diamond- or flame-shaped small forms as well as coarse segmented or unsegmented filaments up to 5 microns in length. Filaments may contain one or more rings, or may be composed in part or entirely of diamond-shaped, coccoid or ovoid elements, sometimes in parallel rows. Rods often show intense bipolar staining. Coccoid forms, usually scattered, may occur as aggregates or clumps on the red cell, apparently embedded in a faint blue matrix.

A pale blue veil-like substance may cover nearly half of one surface of the red cells and show at its border typical red-violet stained rods or filaments in the Giemsa-stained specimens. A bow-shaped arrangement of elements is characteristic. Organisms lie on the surface of the red cells. In cultures organisms are more uniform in morphology resembling *Bartonella bacilliformis*. Individual organisms are fine rods, 0.3 by 1.0 to 2 microns, sometimes occurring in chains and often in clumps. Small round forms occur, measuring 0.5 micron in diameter, and occasionally round disk-like structures.

Cultivation: Growth in Noguchi's semi-solid serum agar 2 weeks after inoculation with citrated or heparinized blood and incubated at 23°C shows as white rounded masses, measuring up to about 1 mm in the upper 15 mm of the tube. In tissue culture the organism grows in small, rounded compact masses within the cytoplasm of infected cells. Indefinite maintenance of the strains isolated on artificial media has not been possible.

Pathogenicity: Splenectomized white mice and splenectomized laboratory reared voles are readily susceptible to infection. No marked anemia or any mortality in heavily infected animals. Splenectomized dogs, white rats and deer mice are not susceptible.

Source and habitat: Erythrocytes of the vole (*Microtus pennsylvanicus pennsylvanicus*) following splenectomy. The natural mode of transmission has not been determined though ticks or mites are suspected.

4. **Haemobartonella tyzzeri** (Weinman and Pinkerton) Weinman. (*Bartonella tyzzeri* Weinman and Pinkerton, Ann. Trop. Med., *32*, 1938, 217; Weinman, Trans. Amer. Philosoph. Soc., *33*, 1944, 314.) Named for Prof. Tyzzer who studied haemobartonellae.

Single or composite rods from about 0.25 micron by 1.4 to 4.0 microns. Occasional granular swellings and enlarged poles. Short rods also occur averaging 0.2 to 0.3 by 0.8 micron and also round forms with diameters of 0.2 to 0.3 micron. Distributed irregularly in the red cells.

Stain intensely red-violet with Giemsa's or May-Grünwald-Giemsa's solutions. Gram-negative.

Cultivation: Initial cultures on Noguchi's semi-solid serum agar obtained irregularly. When incubated at 28°C, colonies appear as isolated white spheres about 1 mm in diameter in the upper 8 mm border of the medium. The clumps are composed of rods and granules, with larger round structures or disks occurring occasionally. Also cultivated on the Zinsser, Wei and Fitzpatrick modification of the Maitland medium. Prolonged maintenance on semi-solid media has not been obtained.

Pathogenicity: Splenectomized haemobartonella-free guinea pigs may be infected by blood or cultures injected subcutaneously or intraperitoneally. Splenectomized *Haemobartonella muris*-free rats are insusceptible when inoculated with infected guinea-pig blood. *Macacus rhesus* monkeys are also in-

susceptible to inoculations of infected blood, tissue and cultures. Infection of the guinea pig is subclinical in its manifestations, probably due to the small number of parasites in the blood. No definite anemia accompanies infection.

Source and habitat: Erythrocytes of the Peruvian guinea pig (*Cavia porcellus*). Has also been encountered in Colombia but not in other parts of the world. Observed in latently infected animals only after splenectomy. The natural mode of transmission is unknown, though the flea may be a possible vector.

5. **Haemobartonella bovis** (Donatien and Lestoquard) Weinman. (Donatien and Lestoquard, Bull. Soc. Path. Exot., *27*, 1934, 652; *Bartonella sergenti* Adler and Ellenbogen, Jour. Comp. Path. and Therap., *47*, 1934, 221; (?) *Bartonella bovis* Rodriguez, Rev. del Inst. Llorente, *13*, 1935, 5; abst. in Bull. Inst. Past., *34*, 1936, 1033; Weinman, Trans. Amer. Philosoph. Soc., N. S., *33*, 1944, 308; *Haemobartonella sergenti* Weinman, *loc. cit.*, 290.) From Latin *bos, bovis*, ox.

Resembles *Haemobartonella muris* and *H. canis*. Occurs as rods, coccobacilli and cocci, singly, in pairs or short chains or groups of 10 or more elements. The rods measure 1.2 to 2 microns in length and are very slender. The coccobacilli occur singly or in pairs measuring 0.3 by 0.6 to 0.8 micron and the diameters of the cocci are about 0.3 micron. The parasite may occupy a central or marginal position on the red cell; the number on a cell varying from 1 to 20. Not more than 20 per cent of the cells are parasitized.

Using the Romanowsky stain, the organisms stain similarly to the chromatin of *Piroplasma spp.*

Source and habitat: In the blood of bulls in Algeria and in a non-splenectomized calf in Palestine.

6. **Haemobartonella sturmanii** Grinberg. (Grinberg, Ann. Trop. Med., *33*, 1939, 33; Weinman, Trans. Amer. Philosoph. Soc., N. S., *33*, 1944, 313.)

Similar to *Haemobartonella bovis* and *H. canis* in morphology and staining properties. Occurs as rods, cocco-bacillary and coccoid forms, varying in length from 0.5 to 1.5 microns. The number of parasites per infected cell varies from 1 to 15 and they occur individually, scattered irregularly in clumps or sometimes in chains stretching across the cell. At the height of the infection more than 90 per cent of the cells are infected.

Pathogenicity: Causes a temperature rise in buffaloes and slight anemia after direct blood inoculation. Splenectomized rabbits, hamsters and splenectomized calves inoculated with blood from infected buffaloes remained free of the parasite.

Source and habitat: In the blood of buffaloes in Palestine.

7. **Haemobartonella peromyscii** Tyzzer. (Proc. Amer. Philos. Soc., *85*, 1942, 377.) Named for the genus of deer mice, *Peromyscus*.

Occurs as delicate filamentous forms (which may be branched) on the red blood cells. These filaments may become beaded and give rise to a number of coccoids and rods from which ring forms may develop.

Stains by Giemsa's method, but staining process must be intense in order to demonstrate the organism.

Pathogenicity: Infection transmissible to splenectomized white rats, white mice and voles, producing a more or less severe illness with anemia.

Habitat: In the blood of the deer mouse (*Peromyscus leucopus noveboracensis*).

7a. *Haemobartonella peromyscii* var. *maniculati* Tyzzer. (Proc. Amer. Philos. Soc., *85*, 1942, 381.) Named for the species of mouse from which it was isolated.

Occurs as rods and filamentous

branched forms. Coarser filaments appear to rise from rounded granules. Delicate rods are preponderant, and minute coccoids appear occasionally. When transferred to the common deer mouse, coarser forms appear, including filaments and large coccoids, sometimes in chains.

Pathogenicity: Pathogenic for gray-backed deer mice and the common deer mouse, but non-infective for splenectomized white mice.

Habitat: Blood of the gray-backed deer mouse (*Peromyscus maniculatus gracilis*).

8. **Haemobartonella blarinae** Tyzzer. (Proc. Amer. Philos. Soc., *85*, 1942, 382.) Named for the genus of shrews, *Blarina*.

Extremely pleomorphic with delicate rods and coccus-like forms, often occurring in chains which also contain larger elements which have a deeply stained, bead-like granule. In the early stages of infection they may occur as thick bands or filaments stretching over the red cells usually with a bead or granule.

The bands take a bluish tint with Geimsa's stain, while the more delicate form stains a slaty violet. The head is distinctly reddish. In the fully developed infection, rods and filaments predominate over rounded forms. The organisms may be scattered on the surface of the red cells or may form a dense cap which is intensely stained. Rudimentary mycelia may be found radiating from a central portion and reddish stained material with ill-defined contours may occur at the ends of the mycelial branches.

Pathogenicity: Pathogenic for the short-tailed shrew but not for deer mice or white mice. Causes anemia in the shrew.

Habitat: In the blood of the short-tailed shrew (*Blarina brevicauda*).

9. **Haemobartonella sciurii** Tyzzer. (Proc. Amer. Philos. Soc., *85*, 1942, 385.) Named for the genus of gray squirrels, *Sciurus*.

Very pleomorphic. Occurs as minute rods and filaments which are continuous or segmented. The rods and filaments vary in thickness, some are very uneven and some very coarse. Beaded chains may develop from the thickened forms.

The bead-like elements stain a dull reddish at the periphery with Giemsa's stain while the remainder is very faintly stained in contrast to the intensely staining basophilic rods and filaments. Some of the rounded forms have the appearance of large, thick rings. Beads and rings may arise from slender deeply staining rods, simulating very closely spores within bacilli, though no germination of filaments from them has been observed.

Pathogenicity: Slightly pathogenic for the gray squirrel, non-pathogenic for normal white mice.

Habitat: Blood of the gray squirrel (*Sciurus carolinensis leucotis*).

Appendix: Here are included (1) *Haemobartonella* of undetermined specific rank, (2) *Haemobartonella*-like structures in non-splenectomized mammals and in cold-blooded animals, (3) Invalid species (see Weinman, Trans. Amer. Philosoph. Soc., N. S., *33*, 1944, 315).

1. Hameobartonellae of undetermined specific rank. Microorganisms are grouped according to host of origin and are considered to be haemobartonellae from the description of the original author; but the information furnished is not sufficient for further classification.

Haemobartonellae similar to *Haemobartonella muris* in wild rats: *Mus decumanus*, *Mus norvegicus*, *Rattus rattus frugivorus*, *Mus rattus griseiventer*, *Mus rattus rattus*, *Mus sylvaticus*. In various rats; technical names not given.

Haemobartonellae similar to *Haemobartonella muris* in albino mice. Schilling (Klin. Wchnschr., 1929, 55) separated the haemobartonella of the mouse from

that of the rat and named it *Bartonella muris musculi* var. *albinoi* (*Haemobartonella muris musculi* var. *albinoi* Weinman, *loc. cit.*, 290).

Haemobartonellae similar to *Haemobartonella muris* in other mammals: *Haemobartonella glis glis* (Kikuth) Weinman (*Bartonella glis glis* Kikuth, Cent. f. Bakt., I Abt., *123*, 1931, 356; Weinman, *loc. cit.*, 317) in dormice (*Glis glis*).

Haemobartonella opossum (Regendanz and Kikuth) Weinman (*Bartonella opossum* Regendanz and Kikuth, Arch. f. Schiffs- u. Tropenhyg., *32*, 1928, 587; Weinman, *loc. cit.*, 290) in the marsupial rat (*Metachirus opossum*) and in the opossum (*Didelphys didelphys*).

Haemobartonella spp. in *Lophuromys ansorgei*, in *Lophuromys laticeps*, in *Oenomys bacchante editus*, in *Praeomys jacksoni*, in *Arvicanthus striatus*, in deer mouse (*Peromyscus leucopus novaboracensis*), in Chinese hamsters (*Cricetulus griseus*, *Cricetulus griseus fumatus*), in *Apodemus agrarius* and *Phodopus praedilectus*), and in squirrels (*Sciurus vulgaris*). Mixed infections, including haemobartonellae are found in jerboa, the gerbille and various rodents (see Weinman, *loc. cit.*, 317–319).

2. Haemobartonella-like structures in non-splenectomized mammals and cold-blooded animals.

Various bodies whose proper classification in the genus *Haemobartonella* has not been established (Weinman, *loc. cit.*, 319)

In non-splenectomized mammals:

Bartonella melloi Yakimoff and Rastegaieff, Bull. Soc. Path. Exot., *24*, 1931, 471 (*Haemobartonella melloi* Weinman, *loc. cit.*, 290) in the ant eater (*Manis pentadactyla*).

Bartonella pseudocebi Pessôa and Prado, Rev. biol. e hyg., *1*, 1927, 116 (*Haemobartonella pseudocebi* Weinman, *loc. cit.*, 290) in the monkey (*Pseudocebus apella*).

Bartonella rocha-limai Faria and Pinto, Compt. rend. Soc. Biol., Paris, *95*, 1926, 1500 (*Haemobartonella rocha-limai* Weinman, *loc. cit.*, 290) in the bat (*Hemiderma brevicauda*).

Bartonella sp. in the rat (*Rattus rufescens*) and *Bartonella sp.* in the dormouse (*Myoxus glis*).

In cold-blooded animals:

Bartonella pavlovskii Epstein, All Union. Inst. Exper. Med., Moscow, 1935, 398, see Ray and Idnani, Indian Jour. Vet. Sci. and Animal Husb. *10*, 1940, 259, (*Haemobartonella pavlovskii*, Weinman *loc. cit.*, 290) in the lamprey (*Petromyzon marinus*).

Bartonella nicollei Yakimoff, Arch. Inst. Pasteur Tunis, *17*, 1928, 350 (*Haemobartonella nicollei* Weinman, *loc. cit.*, 290) in the brochet (*Esox lucius*).

Bartonella ranarum da Cunha and Munez, Compt. rend. Soc. Biol., Paris, *97*, 1927, 1091 (*Haemobartonella ranarum* Weinman, *loc. cit.*, 290) in the frog (*Leptodactylus ocellatus*). This is probably identical with *Bartonella batrachorum* Zavattari, Boll. d. Soc. ital. biol. sper., *6*, 1931, 121 (*Haemobartonella batrachorum* Weinman, *loc. cit.*, 290) from the same species.

Bartonella sp. in the gecko (*Platydactylus mauritanicus*), *Bartonella sp.* in the lizard (*Lacertilia sp.*), *Bartonella sp.* in the lizard (*Tropidurus peruvianus*), *Bartonella sp.* in the tench (*Tinca tinca*) and *Bartonella sp.* in the tortoise (*Testudo graeca*).

3. Invalid species:

Bartonella caviae Campanacci, Ateneo parmense, *1*, 1929, 99 (*Haemobartonella caviae* Weinman, *loc. cit.*, 290) from the guinea pig.

Bartonella ukrainica Rybinsky, Rev. Microbiol. epidem. et parasitol., *8*, 1929, 296 (*Haemobartonella ukrainica* Weinman, *loc. cit.*, 290) from the guinea pig.

Weinman (*loc. cit.*, 314) states that the parasitism of these structures was not proven and no illustrations are furnished by the authors.

Genus III. Grahamella *Brumpt.*

(Brumpt, Bull. Soc. Path. Exot., *4*, 1911, 514; *Grahamia* Tartakowsky, Trav. IX^e Cong. Int. Med. Vet., *4*, 1910, 242; not *Grahamia* Theobald, Colonial Office, Misc. Pub. No. 237, 1909.) Named for G. S. Graham-Smith who discovered the parasite in the blood of voles.

Parasites occurring within the erythrocytes of the lower mammals which morphologically bear a resemblance to *Bartonella*, but which are less pleomorphic, more plump, and more suggestive of the true bacteria. They stain more deeply than bartonellae with Giemsa's stain, stain lightly with aniline dyes and with methylene blue. They are Gram-negative, non-acid-fast and non-motile. Splenectomy has no effect on the source of infection except in rats. They are non-pathogenic and not affected by arsenicals. Several species have been cultivated on cell-free media.* The etiological agent of grahamellosis of rodents and some other vertebrates.

The type species is *Grahamella talpae* Brumpt.

1. **Grahamella talpae** Brumpt. (Bull. Soc. Path. Exot., *4*, 1911, 514.) Named for the genus of moles, *Talpa*.

Long or short rods of irregular contour lying within the red blood cells, many with a marked curve, often near one of the extremities. One or both ends of the longer forms enlarged, giving a wedge- or club-shaped appearance. Some of the medium-sized forms definitely dumbbell-shaped, small forms nearly round.

With Giemsa's stain, the protoplasm of the organism stains light blue, with darker areas at the enlarged ends. Dark staining areas of longer forms give the organism a banded appearance. Length varies from 0.1 to 1 micron. Parasites occasionally free in the plasma, but usually in groups. Most of the infected corpuscles contain between 6 and 20 parasites (Graham-Smith, Jour. Hyg., *5*, 1905, 453).

Pathogenicity: Pathogenic for moles.

Appendix: In addition to *Grahamella talpae* Brumpt, descriptions of the following species occur in the literature. The list may not be complete and the validity of these species may be questioned in some cases.

Grahamella acodoni Carini. (Ann. Parasit., *2*, 1924, 253.) From *Acodon serrensis*, Brazil.

Grahamella alactagae Tartakowsky. (Katalogue der Exponaten der Landwirthschaftlichen Ausstellung (Russisch), St. Petersburg, 1913.) From *Alactaga saliens* and *Alactaga aconitus* in Transcaucasia and steppes of Astrakhan (*Alactaga* misspelled *Alactoga*). Quoted from Yakimoff, Arch. f. Protistenk., *66*, 1929, 303.

Grahamella arvalis Tartakowsky. (Katalogue der Exponaten der Landwirthschaftlichen Ausstellung (Russisch) St. Petersburg, 1913.) From *Microtus arvalis* in Transcaucasia. Quoted from Yakimoff, Arch. f. Protistenk., *66*, 1929, 304.

Grahamella balfourii Brumpt. (*Grahamella sp.* Balfour, Rept., Wellcome Tropical Research Laboratory, *2*, 1906, 97; *Grahamella balfouri* Brumpt, Bull. Soc. Path. Exot., Paris, *4*, 1911, 517.) From the desert rat (*Jaculus jaculus*) in the Sudan.

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* Tyzzer (Proc. Amer. Philos. Soc., *85*, 1942, 375) finds that grahamellae isolated in culture show a close relationship to *Streptobacillus moniliformis* (*Actinomyces muris*) and proposes the inclusion of the genus *Grahamella* in the family *Actinomycetaceae*. The latter relationship appears to be very doubtful.

Grahamella blarinae Tyzzer. (Proc. Amer. Philos. Soc., *85*, 1942, 370.) From the short-tailed shrew (*Blarina brevicauda*) in Massachusetts.

Grahamella bovis Marzinowsky. (Med. Obosrenie, 1917, No. 1–2.) From the ox (*Bos taurus*) in Russia. Quoted from Yakimoff, Arch. f. Protistenk., *66*, 1929, 304.

Grahamella brumptii Ribeyro and del Aquilla. (Ann. Fac. Med., Lima, *1*, 1918, 14–20.) From *Desmodus rufus* in Peru.

Grahamella canis lupus Kamalow. (Cent. f. Bakt., I Abt., Orig., *128*, 1933, 197.) From the wolf, Tiflis.

Grahamella couchi Neitz. (Onderst. Jour. Vet. Sci. and An. Ind., *10*, 1938, 29.) From the multimammate mouse (*Mastomys coucha*) in South Africa.

Grahamella criceti domestici Parzwanidze. (Das Material zum Hämoparasitismus der Tiere bei Uns. Tiflis, 1925.) From *Cricetus domesticus* in Transcaucasia. Quoted from Yakimoff, Arch. f. Protistenk., *66*, 1929, 304.

Grahamella criceluli Patton and Hindle. (Proc. Roy. Soc., London, B(*100*), 1926, 387.) From *Cricetulus griseus* in China.

Grahamella dschunkowskii Tartakowsky. (*Grahamia sp.*, Dschunkowsky and Luhs, Trav. IX. Cong. Internat. Med. Vet., 1909, 4, 1910, 242; *Grahamia dschunkowski* Tartakowsky, 1910.) From the bat (*Vespertilio noctula*) in Transcaucasia. Ref. to Tartakowsky quoted from Yakimoff, Arch. f. Protistenk., *66*, 1929, 304.

Grahamella dudtschenkoi Yakimoff. (*Grahamella sp.*, Dudtschenko, Cent. f. Bakt., I Abt., Orig., *74*, 1914, 241; *Grahamella dudtschenkoi* Yakimoff, Arch. f. Protistenk., *66*, 1929, 304.) From the hamster (*Cricetulus sp.*) in Transbaikal.

Grahamella ehrlichii Yakimoff. (*Grahamella ehrlichi* Yakimoff, Arch. f. Protistenk., *66*, 1929, 305.) From the perch (*Perca fluviatilis*) in Russia.

Grahamella francai Brumpt. (*Grahamella sp.* Franca, Arch. Inst. Bacter. Camara, Pestana, *3*, 1911, 277; *Grahamella francai* Brumpt, Précis de Parasitologie, 2éme éd., 1913, 102.) From the jumping rat (*Eliomys quercinus*) in Portugal.

Grahamella gallinarum Carpano. (Ann Parasit. hum. et comp., *13*, 1935, 238.) From leghorn chickens in Egypt.

Grahamella gerbilli Sassuchin. (*Grahamia gerbilli* Sassuchin, Arch. f. Protistenk., *74*, 1931, 526.) From *Gerbillus tamaricinus* in southeast Russia.

Grahamella hegneri Sassuchin. (*Grahamia hegneri* Sassuchin, Arch. f. Protistenk., *75*, 1931, 152.) From *Citellus pygmaeus* in Russia.

Grahamella joyeuxii Brumpt. (*Grahamella sp.*, Joyeux, Bull. Soc. Path. Exot., Paris, *6*, 1913, 614; *Grahamella joyeuxi* Brumpt, Précis de Parasitologie, 2éme éd., 1913, 102.) From *Golunda fallax* and *Mus rattus* in French Guinea.

Grahamella merionis Adler. (Trans. Roy. Soc. Trop. Med., *24*, 1930, 78.) From *Meriones tristrami* in Palestine.

Grahamella microti Lavier. (Bull. Soc. Path. Exot., Paris, *14*, 1921, 573.) From *Microtus arvalis* in France.

Grahamella microti pennsylvanici Tyzzer. (Proc. Amer. Philos. Soc., *85*, 1942, 366.) From the common vole (*Microtus pennsylvanicus pennsylvanicus*) in Massachusetts.

Grahamella muris Carini. (Bull. Soc. Path. Exot., Paris, *8*, 1915, 104.) From the house rat (*Mus decumanus*) in Brazil.

Grahamella muris musculi iberica Parzwanidze. (Das Material zum Hämoparasitismus der Tiere bei uns. Tiflis, 1925.) From *Mus musculus* in Transcaucasia. Quoted from Yakimoff, Arch. f. Protistenk., *66*, 1929, 304.

Grahamella musculi Benoit-Bazille. (Bull. Soc. Path. Exot., Paris, *13*, 1920, 408.) From *Mus musculus* var. *albinos* in France.

Grahamella ninae kohl-yakomovi Yakimoff. (Bull. Soc. Path. Exot., Paris, *10*,

1917, 99.) From the hamster (*Cricetus phoca*) in Transcaucasia.

Grahamella peromysci Tyzzer. (Proc. Amer. Philos. Soc., *85*, 1942, 363.) From the deer mouse (*P. leucopus noveboracensis*) in Massachusetts.

Grahamella peromysci var. *maniculati* Tyzzer. (Proc. Amer. Philos. Soc., *85*, 1942, 365.) From the gray-backed deer mouse (*Peromyscus maniculatus*) in Massachusetts.

Grahamella phyllotidis Tyzzer. (Proc. Amer. Philos. Soc., *85*, 1942, 371.) From the Peruvian mouse (*Phyllotis darwini linatus*).

Grahamella pipistrelli Markow. (*Grahamia pipistrelli* Markow, Russian Jour. Trop. Med., 1926, No. 5, 52.) From the bat (*Pipistrellus nathusii*) in Russia.

Grahamella rhesi Leger. (Bull. Soc. Path. Exot., Paris, *15*, 1922, 680.) From the monkey (*Macacus rhesus*) in Annam.

Grahamella sanii Cerruti. (Arch. Ital. Sci. Med. Col., *11*, 1930, 522.) From *Testudo graeca* in Sardinia.

Grahamella talassochelys Cerruti. (Arch. Ital. Sci. Med. Col., *12*, 1931, 321.) From *Tallasochelys caretta* in Sardinia. (Misspelled for *Thalassochelys*.)

Genus IV. **Eperythrozoon** *Schilling.**

(Schilling, Klin. Wchnschr., 1928, 1854; *Gyromorpha* Dinger, Nederl. tijdschr. geneesk., *72*, 1928, 5903.) From Greek meaning animal on red blood cell.

Microscopic blood parasites found in the plasma and on the erythrocytes. They stain well with Romanowsky type dyes, and then appear as rings, coccoids or short rods, 1 to 2 microns in greatest dimension, staining bluish or pinkish violet. They show no differentiation of nucleus and cytoplasm. The organisms are not known to retain the violet in Gram's method or to be acid-alcohol-fast. Splenectomy activates latent infection. Not cultivated in cell-free media. Arthropod transmission has been established for one species (Weinman, Trans. Amer. Philosoph. Soc., N.S. *33*, pt. 3, 1944, 321).

The type species is *Eperythrozoon coccoides* Schilling.

Key to the species of genus **Eperythrozoon.**

I. Etiological agent of eperythrozoönosis of white mice.
  1. *Eperythrozoon coccoides.*

II. Etiological agent of eperythrozoönosis of sheep.
  2. *Eperythrozoon ovis.*

III. Etiological agent of eperythrozoönosis of cattle.
  3. *Eperythrozoon wenyonii.*

IV. Etiological agent of eperythrozoönosis of gray-backed deer mice.
  4. *Eperythrozoon varians.*

V. Etiological agent of eperythrozoönosis of voles and dwarf mice.
  5. *Eperythrozoon dispar.*

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* This genus has been considered as belonging to the *Protozoa* by Neitz, Alexander and Du Toit (Onderst. J. Vet. Sci., *3*, 1934, 268) and to the bacteria by Mesnil (Bull. Soc. Path. exot., *22*, 1929, 531 and by Tyzzer (in Weinman, Trans. Amer. Philosoph. Soc., N.S., *33*, pt. 3, 1944, 244). The evidence at hand favors the inclusion of this group among those organisms which are not protozoan in nature but which are closely related to bacteria.

1. **Eperythrozoon coccoides** Schilling. (Schilling, Klin. Wchnschr., 1928, 1854; *Gyromorpha musculi* Dinger, Nederl. tijdschr. geneesk., *72*, 1928, 5905.) From Greek, coccus-shaped.

In stained blood films these organisms appear as rings, coccoids and rods, the majority as rings of regular outline with clear centers. They are in the plasma and on the red cells. Measure 0.5 to 1.4 microns in greatest dimension.

Stain pale red or reddish-blue with the Giemsa or the May-Grünwald-Giemsa technics. Gram-negative.

Suggested methods of multiplication by binary fission, budding, development of small coccoidal to annular forms.

Cultivation: Negative results.

Immunology: Immunological state in animals that of the premunition type. Latent infection in mice which is made manifest by splenectomy.

Pathogenicity: Pathogenic for white mice, rabbits, white rats, wild mice, usually in young animals or in splenectomized adults.

Source: Blood of splenectomized white mice.

Habitat: Blood of infected animals, mouse louse (*Polyplax serrata*) and probably other arthropods.

2. **Eperythrozoon ovis** Neitz, Alexander and Du Toit. (Neitz et al., Address, Biological Society, Pretoria, Mar. 15, 1934; from Neitz, Onderst. Jour. Vet. Sci. and An. Ind., *9*, 1937, 9.) From Latin *ovis*, sheep.

Delicate rings approximately 0.5 to 1.0 micron in diameter though occasionally larger. In addition there are triangles with rounded angles, ovoid, comma, rod, dumbbell and tennis racket forms. Found supra-cellularly on the erythrocytes but often free. Colored pale purple to pinkish-purple with Giemsa's stain. Suggested mode of multiplication by budding.

Cultivation: Negative results.

Immunology: Immunological state in sheep appears to be that of the premunition type.

Pathogenicity: Sheep, antelopes and probably goats and splenectomized calves are susceptible. Dogs, rabbits and guinea pigs are refractory. The distinctive feature of *Eperythrozoon ovis* is its ability to provoke illness in normal animals without resorting to splenectomy.

Source: Blood of infected South African sheep.

Habitat: Blood of infected animals. No ectoparasites found on sheep naturally infected, but an arthropod is suspected.

3. **Eperythrozoon wenyonii** Adler and Ellenbogen. (Adler and Ellenbogen, Jour. Comp. Path. and Therap., *47*, 1934 (Sept. 3), 220; see *Bartonella wenyoni* in appendix.) Named for Dr. C. M. Wenyon, a student of these organisms.

Morphologically similar to *Eperythrozoon coccoides*. Coccoid and often vesicular, staining pale red with Giemsa's stain and varying from 0.2 to 1.5 microns in diameter. Multiplication seems to be by budding and fission, and by filamentous growths from the ring forms, suggesting resemblance to *Hyphomycetes*. Up to 50 or 60 parasites are found on one cell. These are arranged in irregular chains or in tightly packed groups.

Cultivation not reported.

Immunology: The organism creates a state of premunition and latent infection is made manifest by splenectomy.

Pathogenicity: Cattle are susceptible, but sheep are not infected either before or after splenectomy.

Source: Blood of infected cattle.

Habitat: Blood of infected cattle, arthropod transmission not proven.

4. **Eperythrozoon varians** Tyzzer. (Proc. Amer. Philos. Soc., *85*, 1942, 387.) From Latin *varians*, varying.

Occur in rings, coccoids of varying size, some very minute, bacillary forms.

Many of the bacilliform elements show an unstained lens-like swelling, indicating the formation of a ring within the substance of the rod. At the height of the infection most of the organisms are found in the plasma. Whenever an organism comes in contact with a red cell, it stains intensely.

Pathogenesis: Pathogenic for the gray-backed deer mouse (causing anemia) and for the splenectomized common deer mouse. Not pathogenic for splenectomized white mice.

Habitat: Blood of the gray-backed deer mouse (*Peromyscus maniculatus gracilis*).

5. **Eperythrozoon dispar** Bruynoghe and Vassiliadis. (Ann. de Parasitol., 7, 1929, 353.)

Resembles *Eperythrozoon coccoides* in staining, distribution on the erythrocytes and also in appearance except that circular disks with solid staining centers may greatly outnumber the ring forms. Found on the red blood cells and in the plasma. Size range that of *Eperythrozoon coccoides*, also some larger ring forms.

Cultivation: Not successful.

Immunology: Infection is followed by premunition and latent infection is made manifest by splenectomy. Splenectomized rabbits premunized against *E. coccoides* do not react to inoculation with *E. dispar*; if the latter is injected first, they do not react to *E. coccoides*.

Infectivity: Infective for the European vole (*Arvicola* [*Microtus*] *arvalis*), the American vole (*Microtus pennsylvanicus pennsylvanicus*), the dwarf mouse (*Mus minutus*), the rabbit, and *Mus acomys*. Not infective for albino rats or albino mice.

Source: Blood of infected animals.

Appendix: 1) Species incompletely studied, *Eperythrozoon spp.* and *Eperythrozoon*-like structures (Weinman, Trans. Amer. Philosoph. Soc., N. S. *33*, pt. 3, 1944, 320).

Eperythrozoon noguchii Lwoff and Vaucel. (Bull. Soc. path. exot. *26*, 1933, 397.) Probably not a valid species.

Eperythrozoon perekropovi Yakimoff. (Arch. f. Protistenk., *73*, 1931, 271.) Classification in genus *Eperythrozoon* questionable.

Bartonella wenyoni Nieschulz. (Ztschr. f. Infektionskr., *53*, 1938, 178.) Probably identical with *Eperythrozoon wenyoni*. If valid, *Haemobartonella wenyoni*.

Possible human infection (Schüffner, Nederl. tijdschr. v. geneesk., *73*, 1939, 3778).

2) Animals infected with parasites which are definitely eperythrozoön-like but of uncertain specificity or which are eperythrozoön-like in some features but which can not be definitely classified generically:

Jerboa sp. Kikuth. (Cent. f. Bakt., I Abt., Orig., *123*, 1931, 356.)

Arvicola arvalis Zuelzer. (Zuelzer, Cent. f. Bakt., I Abt., Orig., *102*, 1927, 449; Kikuth, Ergebn. Hyg. Bakt., Immunitätsforsch. u. Exper. therap., *13*, 1932, 559.)

Rattus rattus Schwetz. (Ann. Soc. belge de med. trop., *14*, 1934, 277.)

Sciurus vulgaris Nauck. (Arch. f. Schiffs- u. Trop.-Hyg., *31*, 1927, 322.)

Leptodactylus pentadactylus Carini. (Compt. rend. Soc. Biol., Paris, *103*, 1930, 1312.)

FAMILY III. CHLAMYDOZOACEAE MOSHKOVSKY.*

(Uspekhi Souremennoi Biologii (Russian) (Advances in Modern Biology), *19*, 1945, 12.)

Small, pleomorphic, often coccoid microorganisms usually with characteristic development cycle. Stain with aniline dyes. Gram-negative. Behave as obligate intracytoplasmic parasites. Have not been cultivated in cell-free media. Criteria adequate for classification lacking for more recently isolated members. The attribution of Genus III, *Colesiota*, either to *Rickettsiaceae* or to *Chlamydozoaceae* is still in doubt.

Key to the genera of family **Chlamydozoaceae.**

I. Cells coccoid and with life cycle.
  A. Non-cultivatable in chicken embryonic tissues.
    Genus I. *Chlamydozoon*, p. 1114.
  B. Cultivatable in chicken embryonic tissues.
    Genus II. *Miyagawanella*, p. 1115.
II. Cells pleomorphic.
    Genus III. *Colesiota*, p. 1119.

Genus I. **Chlamydozoon** *Halberstaedter and von Prowazek.*

(Arb. a. d. kaiserl. Gesundheitsamte, *26*, 1907, 44.) From Greek *chlamydos*, cloak and *zoon*, animal.

Coccoid spherical cells with developmental cycle. Gram-negative. Intracytoplasmic habitat. Non-cultivatable in chicken embryonic tissues. Susceptible to sulfonamide and penicillin action.

The type species is *Chlamydozoon trachomatis* Foley and Parrot.

1. **Chlamydozoon trachomatis** Foley and Parrot. (*Rickettsia trachomae* Busacca, Arch. Ophthalm., *52*, 1935, 567; Foley and Parrot, Arch. Inst. Past. d'Algérie, *15*, 1937, 339; *Rickettsia trachomatis* Foley and Parrot, *idem.*) Named for the disease, trachoma.

Coccoid bodies: Small microorganisms 200 to 350 millimicrons in diameter form the elementary bodies. Initial bodies up to 800 millimicrons in diameter and plaques up to 10 microns also found. All larger forms encapsulated with substance derived either from the agent or from the cytoplasm of the parasitized cells. Elementary body is the basic unit. Paired forms or clusters occur. Gram-negative. Stains poorly with aniline dyes; blue or reddish-blue with the Giemsa stain and red or blue, depending on the metabolic state, with the Macchiavello stain. Matrix of plaques gives a strong reaction for glycogen. Non-motile.

Cultivation: Has never been cultivated.

Immunological aspects: Has one or more antigens in common with or closely resembling one or more present in *Miyagawanella spp.* Produces, in low concentrations, antibodies which fix complement with antigen from *Miyagawanella lymphogranulomatis*.

Pathogenicity: Pathogenic for man, apes and monkeys where it affects only

* Prepared by Dr. Geoffrey Rake, The Squibb Institute for Medical Research, New Brunswick, New Jersey, September, 1946.

the cornea and conjunctiva causing highly destructive lesions.

Chemotherapy: Susceptible to sulfonamides and penicillin.

Source: Found in scrapings of cornea or conjunctiva in cases of trachoma.

Habitat: The etiological agent of trachoma in man.

2. **Chlamydozoon oculogenitale** Moshkovsky. (Moshkovsky, Uspekhi Sourемennoi Biologii, *19*, 1945, 12.) From Latin *oculus*, eye and *genitalis*, genital.

Morphology and staining reactions: As for *Chlamydozoon trachomatis*.

Cultivation: Has never been cultivated.

Immunological aspects: As for *C. trachomatis*.

Pathogenicity: Pathogenic for man, baboons and monkeys. Causes an acute conjunctivitis and, in man, an inflammation of the lower genito-urinary tract.

Chemotherapy: Susceptible to sulfonamides and penicillin.

Source: Found in conjunctival exudates, and in exudates from infected urethra or cervix. Also present in contaminated pools of water.

Habitat: The etiological agent of swimming pool conjunctivitis, neonatal conjunctivitis or inclusion conjunctivitis.

Genus II. **Miyagawanella** *Brumpt.*

(Ann. de Parasit., *16*, 1938, 153.) Named for Prof. Miyagawa, the Japanese bacteriologist, who first (1935) grew the type species in the chick embryo.

Coccoid to spherical cells with a developmental cycle. Gram-negative. Intracytoplasmic habitat. Cultivatable in chicken embryonic tissues. Some species are susceptible to sulfonamide or penicillin action.

The type species is *Miyagawanella lymphogranulomatis* Brumpt.

Key to the species of genus **Miyagawanella.**

I. The etiological agent of lymphogranuloma venereum, lymphogranuloma inguinale, climatic bubo, and esthiomène in man.
   1. *Miyagawanella lymphogranulomatis.*

II. The etiological agent of psittacosis or parrot fever.
   2. *Miyagawanella psittaci.*

III. The etiological agent of ornithosis (Meyer).
   3. *Miyagawanella ornithosis.*

IV. The etiological agent of one type of viral pneumonia.
   4. *Miyagawanella pneumoniae.*

V. The etiological agent of mouse pneumonitis (Gönnert).
   5. *Miyagawanella bronchopneumoniae.*

VI. The etiological agent of feline pneumonitis (Baker).
   6. *Miyagawanella felis.*

VII. The etiological agent of Louisiana pneumonia.
   7. *Miyagawanella louisianae.*

VIII. The etiological agent called the Illinois virus, the cause of one type of viral pneumonia.
   8. *Miyagawanella illini.*

1. **Miyagawanella lymphogranulomatis** Brumpt. (Brumpt, Ann. de Parasit., *16*, 1938, 153; *Ehrlichia lymphogranulomatosis* Mauro, (Reference not found.) Named for the disease, lymphogranuloma.

Coccoid bodies: Small microorganisms 200 to 350 millimicrons in diameter form the elementary bodies. Initial bodies up to 1 micron and plaques up to 10 microns also found. All larger forms encapsulated with a substance derived either from the agent or from the cytoplasm of parasitized cells. Elementary body is the basic unit. Paired forms or clusters occur. Gram-negative. Stain with aniline dyes, purple with the Giemsa stain and red or blue, depending on metabolic state, with the Macchiavello stain. Matrix of the plaque does not give the reaction for glycogen. Non-motile.

Filterability: Passes through Chamberland L_2 and L_3, Berkefeld V and N and sometimes through Seitz EK filters.

Cultivation: In plasma tissue cultures of mammalian cells, in mammalian cells on agar, in the chorio-allantoic membrane or particularly in the yolk sac of the chicken embryo but has not been cultivated in the allantoic sac. Optimum temperature 37°C in tissue cultures, 35°C in the chicken embryo.

Immunological aspects: Has one or more antigens in common with or closely resembling one or more present in the chlamydozoa and other miyagawanellae. Antisera against any of these two genera react with antigens from *Miyagawanella lymphogranulomatis* or the other miyagawanellae thus far tested. One common antigen has been isolated as a soluble fraction distinct from the bodies of the agent. Distinguished sharply from the other miyagawanellae by antitoxic neutralization of toxic factor or by neutralization of infections in mice with chicken antisera. Evidence exists that these two serological reactions are with distinct specific antigens. Immunity in man or animals is probably poor in the absence of continuing apparent or inapparent infection.

Toxic factor: Infected yolk sac or yolk injected intravenously or intraperitoneally is rapidly fatal to mice. Produces characteristic lesions on the skin of normal guinea pigs.

Pathogenicity: Pathogenic for man, apes, monkeys, guinea pigs, cotton rats, hamsters, mice, chicken embryos. Inapparent infections may occur with the agent harbored in the organs. Causes local genital lesions, septicemia, lymphadenitis, meningitis, ophthalmitis and rarely pneumonitis in man.

Tissue tropisms: In laboratory rodents this species is infective by the intranasal (pneumonitis), the intracerebral (meningitis) and the intradermal routes.

Chemotherapy: Susceptible to relatively high concentrations of penicillin, to the sulfonamides and to some antimony compounds.

Source: Most commonly the genital secretions of infected individual or the draining lymph nodes. Also occasionally in blood, spinal fluid and ocular secretions.

Habitat: The etiological agent of lymphogranuloma venereum, lymphogranuloma inguinale, climatic bubo, esthiomène and some forms of anorectal inflammation.

2. **Miyagawanella psittaci** (Lillie) Moshkovsky. (*Rickettsia psittaci* Lillie, Publ. Health Repts., *45*, 1930, 773; *Microbacterium multiforme psittacosis* Levinthal,* 1st Cong. internat. de Microbiol., *1*, 1930, 523; Moshkovsky, Uspekhi Souremennoi Biologii (Russian) (Advances in Modern Biology), *19*, 1945, 12; *Ehrlichia psittaci* Moshkovsky, *ibid.*, *19*.) From *Psittaci*, an order of birds.

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* This is the type species of the genus *Microbacterium* Levinthal which is invalid because of the earlier *Microbacterium* Orla-Jensen, 1919, see p. 370.

Coccoid bodies: As for *Miyagawanella lymphogranulomatis*.

Filterability: Partly filterable through Berkefeld N, Chamberland L and Q or Seitz EK filters.

Cultivation: As for *Miyagawanella lymphogranulomatis* but grows readily in allantoic sac without adaptation.

Immunological aspects: As for *M. lymphogranulomatis* but no soluble fraction yet demonstrated.

Toxic factor: Infected yolk sac or yolk injected intravenously or intraperitoneally is rapidly fatal to mice.

Pathogenicity: Pathogenic for birds (particularly psittacine and finch species), man, monkeys, guinea pigs, pocket gophers, hamsters, white rats, kangaroo rats, mice, rabbits and chicken embryos. Inapparent infections may occur with the agent harbored in the organs. Causes a highly fatal pneumonitis with septicemia in man.

Tissue tropisms: Causes a septicemia. In man this species shows predilection for the respiratory tract. In laboratory rodents, it is infective by the intranasal, the intraperitoneal (peritonitis and septicemia), the intracerebral and the intravenous routes.

Chemotherapy: Susceptible to relatively high concentrations of penicillin. Some strains are susceptible to sulfonamides.

Source: Found in the organs and nasal secretions of infected birds and, from the latter, spreads to the plumage by preening and other methods. Plentiful in droppings or dust from infected cages. Relatively resistant under such conditions.

Habitat: The etiological agent of psittacosis or parrot fever. Also of some cases of atypical pneumonia.

3. Miyagawanella ornithosis Rake, *spec. nov.* From Greek *ornithos*, bird.

Coccoid bodies: As for *Miyagawanella lymphogranulomatis*.

Cultivation: As for *Miyagawanella psittaci*.

Immunological aspects: Has one or more antigens in common with, or closely resembling, one or more present in chlamydozoa and other miyagawanellae as shown by a cross reaction in complement fixation tests. Sharply distinguished from other miyagawanellae by toxin-antitoxin neutralization or by neutralization of infection in mice with chicken antisera. The latter test however suggests that the agent of meningopneumonitis (Francis and Magill, Jour. Exp. Med., *68*, 1938, 147) is this species rather than something distinct. Immunity in man or animals is probably poor except in the presence of continuing apparent or inapparent infections. Cross reactions suggest that *Miyagawanella ornithosis* may be more closely related to *Miyagawanella lymphogranulomatis* than is *M. psittaci*.

Toxic factor: As for *Miyagawanella psittaci*.

Pathogenicity: Pathogenic for birds (especially non-psittacine species), man, ferrets, guinea pigs, hamsters, white rats, kangaroo rats, mice, rabbits and chicken embryos. Inapparent infections may occur. Causes a moderately severe pneumonitis with septicemia in man.

Tissue tropisms: Causes a septicemia. In birds and man shows a predilection for the lungs. In laboratory rodents, this species is infective by the intranasal, intracerebral, intravenous and (with relatively large inocula of most strains) intraperitoneal routes.

Chemotherapy: Susceptible to relatively large doses of penicillin. Not susceptible to sulfonamides.

Source: Found in organs and nasal secretions of finches, pheasants (including domestic chickens), domesticated doves, fulmar petrels and other birds. Spreads from the secretions to plumage and droppings.

Habitat: The etiological agent of ornithosis (Meyer) and meningopneumonitis (Francis and Magill).

4. **Miyagawanella pneumoniae** Rake, *spec. nov.* Named for the disease, pneumonia.

Coccoid bodies: As for *Miyagawanella lymphogranulomatis* but slightly smaller, circa 200 millimicrons in diameter.

Cultivation: As for *Miyagawanella psittaci*.

Immunological aspects: As for *Miyagawanella psittaci*. Distinct from *Miyagawanella ornithosis* by the neutralization test with chicken antisera.

Pathogenicity: Pathogenic for birds, man, cotton rats, hamsters, white rats, kangaroo rats, mice and chicken embryos. Causes a fatal pneumonitis in man.

Tissue tropisms: As for *Miyagawanella ornithosis*.

Chemotherapy: As for *Miyagawanella ornithosis*.

Source: Occurs in lungs of infected humans. Possibly originally of avian origin.

Habitat: The etiological agent of one type of viral pneumonia. The type strain is the so-called strain S-F (Eaton, Beck and Pearson, Journ. Exp. Med., *73*, 1941, 641).

5. **Miyagawanella bronchopneumoniae** Moshkovsky. (Moshkovsky, Uspekhi Souremennoi Biologii, *19*, 1945, 19; *Ehrlichia bronchopneumoniae* Moshkovsky, *idem.*) Named for the disease, bronchopneumonia.

Coccoid bodies: As for *Miyagawanella pneumoniae*.

Cultivation: As for *Miyagawanella lymphogranulomatis*. Does not grow in the allantoic cavity of the chick.

Immunological aspects: As for *Miyagawanella lymphogranulomatis* but no soluble antigen has been demonstrated.

Toxic factor: Heavily infected yolk sacs and yolk injected intravenously are very rapidly fatal to mice.

Pathogenicity: Pathogenic for mice, hamsters and ferrets. Produces a moderately severe pneumonitis.

Tissue tropisms: Shows a predilection for the lungs. In mice, it is also infective by the intravenous route.

Chemotherapy: Susceptible to sulfonamides and to relatively large doses of penicillin.

Source: Found in lungs of certain stocks of the laboratory mouse.

Habitat: The agent of mouse pneumonitis. Bronchopneumonie virus (Gönnert, Cent. f. Bakt., I Abt., Orig., *147*, 1941, 151).

6. **Miyagawanella felis** Rake, *spec. nov.* From Latin *felis*, cat.

Coccoid bodies: As for *Miyagawanella lymphogranulomatis*.

Cultivation: As for *Miyagawanella psittaci*.

Immunological aspects: As for *Miyagawanella psittaci* but nothing known about inapparent infections in the natural host, the domestic cat.

Toxic factor: Infected yolk sac or other membranes and yolk or other fluids, injected intravenously into mice or chicken embryos or intraperitoneally into mice are rapidly fatal.

Pathogenicity: Pathogenic for cats, hamsters, mice and chicken embryos. Causes a fatal pneumonitis with acute conjunctivitis in cats.

Tissue tropisms: Prediliction for lungs and conjunctivae. In laboratory rodents, this species is infective by the intranasal, intraperitoneal, intracerebral and intravenous routes.

Chemotherapy: As for *Miyagawanella ornithosis*.

Source: Lungs of infected cats.

Habitat: The etiological agent of one form of cat nasal catarrh, influenza or distemper (Baker, Science, *96*, 1942, 475) and feline pneumonitis.

7. **Miyagawanella louisianae** Rake, *spec. nov.* Named for the State of Louisiana.

Coccoid bodies: As for *Miyagawanella psittaci*.

Filterability: Filters through Berkefeld N and Mandler 6, 7 and 9 filters.

Cultivation: In the yolk sac of the chicken embryo.

Immunological aspects: Indistinguishable from other miyagawanellae by complement fixation tests with yolk sac antigens. Partly distinguished from *Miyagawanella psittaci* and *M. ornithosis* by active immunization in mice and guinea pigs.

Pathogenicity: Pathogenic for man, guinea pigs, cotton rats, mice and chicken embryos. Slightly pathogenic for white rats, golden hamsters and deer mice. *Macacus rhesus* monkeys, rabbits, muskrats and nutria are unaffected. Causes a highly fatal pneumonitis and septicemia in man.

Tissue tropisms: Causes a septicemia. In man this species shows predilection for the respiratory tract. In laboratory rodents it is infective by the intranasal, intraperitoneal, intracerebral, intramuscular and subcutaneous routes.

Chemotherapy: As for *Miyagawanella ornithosis*.

Source: Sputum and organs of infected persons.

Habitat: The etiological agent of Louisiana pneumonia (Olson and Larson, U. S. Pub. Health Repts., *59*, 1944, 1373), so-called Borg strain.

8. **Miyagawanella illini** Rake, *spec. nov.* Named for the State of Illinois.

Coccoid bodies: As for *Miyagawanella lymphogranulomatis*.

Filterability: Passes through Berkefeld N or W filters.

Cultivation: In the yolk sac of chicken embryo.

Immunological aspects: Distinguished from other miyagawanellae by neutralization tests in mice with chicken antisera and partly from *Miyagawanella psittaci*, *M. ornithosis* and *M. pneumonia* by active immunization in mice.

Pathogenicity: Pathogenic for man and white mice. Causes a highly fatal pneumonitis in man.

Tissue tropisms: Infective in mice by the intranasal, intraperitoneal, intracerebral and subcutaneous routes.

Source: Lungs of infected persons.

Habitat: The etiological agent called the Illinois virus (Zichis and Shaughnessy, Science, *102*, 1945, 301).

Genus III. **Colesiota** Rake, *gen. nov.*

(*Rickettsia* Coles, 17th Rept. Direct. Vet. Serv. and An. Ind. Un. South Africa, 1931, 175.) Named for Prof. Coles who first studied these organisms.

Pleomorphic cells which may be coccoid, triangular, rod-shaped or in the form of rings. Gram-negative. Intracytoplasmic habitat.

The type species is *Colesiota conjunctivae* (Coles) Rake.

1. **Colesiota conjunctivae** (Coles) Rake, *comb. nov.* (*Rickettsia conjunctivae* Coles, 17th Rept. Direct. Vet. Serv. and An. Ind. Un. South Africa, 1931, 175; *Chlamydozoon conjunctivae* Moshkovsky, Uspekhi Souremennoi Biologii, *19*, 1945, 19.) From M. L. *conjunctiva*, the conjunctiva.

Pleomorphic bodies: Average diameter 600 to 950 millimicrons. May be solid and coccoid, rod-shaped, or triangular, or in form of open rings or horse-shoes. No chains. Masses frequent. No capsule. Stains with ordinary aniline dyes but less intensely than bacteria. Gram-negative. Non-motile.

Cultivation: Has never been cultivated.

Immunological aspects: Unknown.

Pathogenicity: Pathogenic for sheep, cattle and goats. Causes acute conjunctivitis and keratitis.

Tissue tropisms: Affects only the conjunctiva and cornea.

Habitat: Found in scrapings of cornea or conjunctiva or in discharges from affected eyes. Etiological agent of infectious or specific ophthalmia in sheep, cattle and goats.

2. **Colesiota conjunctivae-gallii** (Coles) Rake, *comb. nov.* (*Rickettsia conjunctivae-galli* Coles, Onders. Jour. Vet. Sci. and Indust., *14*, 1940, 469.) From conjunctiva and Latin *gallus*, hen.

Pleomorphic bodies: Similar to *Colesiota conjunctivae*. Stain purplish-red or blue with the Giemsa stain.

Cultivation: Has never been cultivated.

Immunological aspects: Unknown.

Pathogenicity: Pathogenic for the domestic fowl. Causes an acute conjunctivitis and keratitis.

Tissue tropisms: As for *Colesiota conjunctivae*.

Source: As for *Colesiota conjunctivae*.

Habitat: The etiological agent of one form of ocular roup in fowls.

Appendix: The following are similar to or identical with the above:

Rickettsia conjunctivae-bovis (Coles, South Afr. Vet. Med. Assoc., 7, 1936, 1) cannot be distinguished from *Colesiota conjunctivae* by any described characteristics.

Rickettsia lestoquardi Donatien and Gayot. (Bull. Soc. Path. Exot., *35*, 1942, 325.) Found in benign conjunctivitis in swine similar to that which occurs in ruminants.

* **Appendix to Order Rickettsiales:** The following are described species of intracytoplasmic and intranuclear parasites of *Protozoa* whose relationships to similar parasites of arthropods and vertebrates are not yet clear. All of the protozoon intracellular parasites are of larger size than typical members of *Rickettsiales* and some have been placed in genera (*Cladothrix*, *Micrococcus*) where the typical species do not live intracellularly.

Genus A. **Caryococcus** *Dangeard.*

(Compt. rend. Acad. Sci., Paris, *134*, 1902, 1365.)

Genus established for a bacterial parasite of the nucleus of *Euglena;* organisms rounded.

The type species is *Caryococcus hypertrophicus* Dangeard.

1. **Caryococcus hypertrophicus** Dangeard. (Compt. rend. Acad. Sci., Paris, *134*, 1902, 1365.) Parasitic in the nucleus of a flagellate (*Euglena deses*).

Occurs in the nucleus as an agglomeration of close-set, rounded corpuscles. The nucleus increases considerably in volume, the chromatin is reduced to thin layers against the membrane, the interior of the nucleus is divided into irregular compartments by chromatic trabeculae.

2. **Caryococcus cretus** Kirby. (Univ. Calif. Publ. Zool., *49*, 1944, 240.) Parasitic in the nucleus of a flagellate (*Trichonympha corbula*) from the intestine of a termite (*Procryptotermes sp.*), Madagascar.

Spherules 1 to 1.5 microns or more in diameter, in preparations appearing clear with usually a chromatic, sharply defined, crescentic structure peripherally or interiorly situated, sometimes with two such bodies or several chromatic granules; parasitic in nucleus; parasitized nucleus enlarged only moderately or not at all, chromatin altered but not greatly diminished in amount.

3. **Caryococcus dilatator** Kirby. (Univ. Calif. Publ. Zool., *49*, 1944, 238.) Parasitic in the nucleus of flagellates (*Trichonympha chattoni* and other species of *Trichonympha*) from the intestine of termites (*Glyptotermes iridipennis*), Australia, and other species.

Spherules 0.5 micron or less in diameter, internally differentiated with stainable granule or stainable region peripherally situated; parasitic in nucleus and nucleolus; nucleus becomes greatly enlarged and the c hromatin mostly or entirely disappears.

4. **Caryococcus invadens** Kirby. (Univ. Calif. Publ. Zool., *49*, 1944, 238.) Parasitic in the nucleus of a flagellate (*Trichonympha peplophora*) from the intestine of a termite (*Neotermes howa*), Madagascar.

Spherules 1 to 1.5 microns in diameter, sometimes arranged in pairs, often internally differentiated with stainable central or peripheral granules or stained areas; parasitic in the nucleolus or endosome and nucleus; parasitized nucleolus becoming greatly enlarged and crossed by trabeculae, eventually consumed; nucleus becoming moderately enlarged, but chromatin not disappearing.

5. **Caryococcus nucleophagus** Kirby. (Univ. Calif. Publ. Zool., *49*, 1944, 236.) Parasitic in the nucleus of a flagellate (*Trichonympha corbula*) from the intestine of termites (*Procryptotermes sp.*), Madagascar, and three species of *Kalotermes* (s. l.) from Madagascar.

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* **Prepared by Prof. Harold Kirby, Jr., University of California, Berkeley, California, October, 1946.**

Spherules with a diameter of about 0.5 micron, sometimes arranged in pairs, sometimes with a thicker, crescentic, stainable area of the periphery on one side; parasitic within the nucleus, exterior or interior to the chromatin mass, which may be diminished in amount, but does not disappear, nor is the parasitized nucleus appreciably enlarged.

Genus B. **Drepanospira** *Petschenko.*

(Arch. f. Protistenk., *22*, 1911, 282.)

Cell incurved in two spiral turns that are not abrupt, one of the ends pointed, the other a little rounded, no flagella, movement helicoid by means of all the body, no cell division, endospores formed, regular spherical colonies formed by individuals at certain stages of development.

The type species is *Drepanospira mülleri* Petschenko.

1. **Drepanospira mülleri** Petschenko. (*Müllerina paramecii* Petschenko, Cent. f. Bakt., I Abt., Orig., *56*, 1910, 90; Petschenko, Arch. f. Protistenk., *22*, 1911, 252; see also Kirby, in Calkins and Summers, Protozoa in Biological Research, 1941, 1036.) Parasitic in the cytoplasm of *Paramecium caudatum.*

Developing from a group of curved rods in the cytoplasm to a large, ellipsoidal mass almost filling the body. Nuclear portion occupying part of the cell.

The author regards this genus as belonging in the family *Spirillaceae* between *Spirosoma* and *Microspira.*

Genus C. **Holospora** *Haffkine.*

(Ann. Inst. Past., *4*, 1890, 151.)

Genus established for bacterial parasites of the ciliate, *Paramecium aurelia* (= *Paramecium caudatum ?*).

The type species is *Holospora undulata* Haffkine.

1. **Holospora undulata** Haffkine. (Ann. Inst. Past., Paris, *4*, 1890, 151.) In the micronucleus of the ciliate *Paramecium aurelia* (= *P. caudatum?*).

Gradually tapered at ends; 1½, 2 and 2½ spiral turns; develops from a small, fusiform body which grows and divides transversely; brings about a great enlargement of the micronucleus, which becomes filled with the spirals (see *Drepanospira mülleri* Petschenko).

2. **Holospora elegans** Haffkine. (Haffkine, Ann. Inst. Past., Paris, *4*, 1890, 154; see also Kirby, in Calkins and Summers, Protozoa in Biological Research, New York, 1941, 1035.) In the micronucleus of the ciliate, *Paramecium aurelia* (= *P. caudatum ?*).

Vegetative stage fusiform; elongated, elliptical, nucleus-like body in some; divides equatorially, budding at one end; transformation into spore entails enlargement, clear space separating membrane at sides, spore pointed at ends.

3. **Holospora obtusa** Haffkin. (Haffkine, Ann. Inst. Past., Paris, *4*, 1890, 153; also see Fiveiskaja, Arch. f. Protistenk., *65*, 1929, 276.) In the macronucleus of the ciliate *Paramecium aurelia* (= *P. caudatum ?*).

Spores not spiralled and both ends are rounded. Reproduction by fission, also by formation of a bud at one of the extremities of the fusiform cell. Bodies with rounded ends 12 to 30 microns long; also spindle-shaped bodies with pointed

ends, 0.5 by 3 to 6 microns (Fiveiskaja, *loc. cit.*).

The following species have been placed in genera belonging in the orders *Chlamydobacteriales* and *Eubacteriales* respectively:

Cladothrix pelomyxae Veley. (Veley, Jour. Linn. Soc., Zool., *29*, 1905, 375; see also Leiner, Arch. f. Protistenk., *47* 1924, 282; Kirby, in Calkins and Summers, Protozoa in Biological Research, New York, 1941, 1025; Hollande, Bull. Biol. France Belg., *79*, 1945, 49.) In the cytoplasm of the rhizopod, *Pelomyxa palustris* and probably also other species of *Pelomyxa*.

Rods, 1.5 to 22 microns or more in length, divided into several to many sections by transverse partitions, generally aggregated in proximity to the nuclei, which may be thickly invested by close-set bacteria applied to the surface.

Micrococcus batrochorum (*sic*) Yakimoff. (Arch. f. Protistenk., *72*, 1930, 137.) In the cytoplasm of the flagellate, *Trichomonas batrachorum* from the tree toad (*Hyla arborea*). Also seen free in preparations of the intestinal contents of *Hyla*.

Round, 1 to 1.5 microns in diameter, grouped generally in aggregates of irregular form, but also occur individually.

NOTE: Further descriptions of bacterial and other parasites of *Protozoa* with bibliography will be found in Calkins and Summers, Protozoa in Biological Research, New York, 1941, 1009-1113 and in Kirby, Univ. of Calif. Pub. in Zoology, *53* 1946, 193-207.

SUPPLEMENT NO. 2

ORDER VIRALES
THE FILTERABLE VIRUSES

FILTERABLE VIRUSES*

The so-called filterable viruses, today generally called merely viruses, are still of unknown affiliations so far as relationships to established groups of microorganisms are concerned. They are treated here as members of an order, consisting of 13 families, 32 genera and 248 species.

Among viruses as we know them, there are three constituent groups that have come to be recognized, and to some extent named and classified, through the largely separate efforts of bacteriologists, animal pathologists, and plant pathologists. Taxonomic overlapping of the three groups, viruses affecting bacteria, viruses having only animal hosts, and viruses invading higher plants, can hardly be justified as yet by available evidence. Nevertheless it has been shown that a single virus may multiply both in a plant host and in an insect vector. This seems to dispose of the thought that adaptation to a plant or animal environment would necessarily preclude utilization of other sources of the materials needed for multiplication.

For the present it seems feasible to continue with the custom, tacitly accepted in the past, of classifying bacteriophages separately as one sub-group, viruses causing diseases in seed plants as a second sub-group, and those causing diseases in animals as a third sub-group. It should be recognized that this may prove to be only a temporary arrangement, necessary because we have no evidence to warrant taxonomic overlapping of the three groups and useful while we await critical investigations and possible development of a substitute plan capable of displaying natural relationships to better advantage. Eventually evidence may become available to show that some bacteriophages can infect higher plants or animals and can increase in the new environment, or that viruses known to attack animals or plants can similarly enlarge their host ranges. Or, there may be discoveries of common physical properties that would aid in formulating an interlocking classification, for which at present we lack any substantial basis.

It is of especial significance now that the three fields be unified at least by a parallel development of nomenclature. Toward this end the present section of this supplement is directed.

*** Supplement No. 2 has been prepared by Francis O. Holmes, The Rockefeller Institute for Medical Research, Princeton, N. J., September, 1944. In this section, authorities for the names of plant hosts are in general as given by Gray's New Manual of Botany, 7th edition, and Bailey's Manual of Cultivated Plants, 1938; in each of these standard works will be found a list of abbreviations customarily used in botany in citing authorities for binomials.**

ORDER VIRALES Breed, Murray and Hitchens.

(Jour. Bact., *47*, 1944, 421.)

Viruses. Etiological agents of disease, typically of small size and capable of passing filters that retain bacteria, increasing only in the presence of living cells, giving rise to new strains by mutation, not arising *de novo*. A considerable number of viruses have not been proved filterable; it is nevertheless customary to include these viruses with those known to be filterable, because of similarities in other attributes and in the diseases induced. Some not known to be filterable are inoculable only by special techniques, as by grafting or by use of insect vectors, and suitable methods for testing their filterability have not been developed; moreover, it is not certain that so simple a criterion as size measured in terms of filterability will prove to be an adequate indicator of the limits of the natural group. Cause diseases of bacteria, plants and animals.

Key to the suborders of order **Virales.**

I. Infecting bacteria.
  Suborder I. *Phagineae*, p. 1128.
II. Infecting higher plants.
  Suborder II. *Phytophagineae* p. 1145.
III. Infecting animals (insects, mammals).
  Suborder III. *Zoophagineae*, p. 1225.

SUBORDER I. **Phagineae** *subordo novus.*

Viruses pathogenic in bacteria; bacteriophages. Containing at present only one family, the *Phagaceae*.

FAMILY I. PHAGACEAE HOLMES.

(Handb. Phytopath. Viruses,* 1939, 1.)

Characters those of the suborder. There is a single genus.

Genus I. **Phagus** *Holmes.*

(*Loc. cit.*, 1.)

Characters those of the family. Generic name from Greek *phagein*, to eat.

The type species is *Phagus minimus* Holmes.

NOTE: *Bacteriophagum* d'Herelle (Compt. rend. Soc. Biol., Paris, *81*, 1918, 1161) a genus name applied in connection with early studies of bacteriophages, had as its type species *Bacteriophagum intestinale* d'Herelle, a bacteriophage that is not now identifiable or, more probably, a mixture of such unidentifiable bacteriophages, for filtrates containing it were said to be capable of killing outright a culture of bacteria (*ibid.*, 1160). The genus name *Bacteriophagum* is, therefore, regarded as a *nomen dubium*, if not also a *nomen confusum;* subsequently it was abandoned by its author, for reasons that are not clear, in favor of the genus name *Protobios* d'Herelle 1924 (Immunity in natural infectious disease; page 343 of authorized English edition by George H. Smith, Baltimore, Williams & Wilkins Co., 1924, 399 pp). *Protobios protobios*

* Holmes, F. O., Handbook of Phytopathogenic Viruses, Burgess Publishing Company, Minneapolis, Minn., 1939, 221 pp.

d'Herelle (*loc. cit.*, 345), presumably the type species of this genus, was not an ordinary virus but was said to be non-parasitic (i.e., free-living) in nature, was capable of reducing sulphur, and is not now identifiable. The genus name *Protobios* and the corresponding binomial *Protobios bacteriophagus* d'Herelle are therefore regarded also as *nomina dubia* and are not used here. *Bacteriophagus* Thornberry (Phytopath., *31*, 1941, 23) appears to represent a variant spelling of d'Herelle's earlier genus name; it was not accompanied by any indication of what recognizable single bacteriophage served as type and thus does not modify the standing of *Bacteriophagum*.

Key to the species of genus **Phagus.**

I. Dysentery-coli bacteriophages.

A. Producing large plaques, 8 to 12 mm in diameter.

1. Particle size small, 8 to 12 millimicrons.

1. *Phagus minimus.*

2. Particle size 15 to 20 millimicrons.

2. *Phagus minor.*

B. Producing moderately large plaques, 2 to 6 mm in diameter, with distinct halo.

1. Particle size 20 to 30 millimicrons.

3. *Phagus parvus.*
4. *Phagus primarius.*
5. *Phagus secundarius.*
6. *Phagus dysenteriae.*

C. Plaques medium size, 1 to 3 mm in diameter, with distinct halo.

1. Particle size 25 to 40 millimicrons.

7. *Phagus medius.*
8. *Phagus astrictus.*

D. Plaques small, 0.5 to 1.5 mm in diameter, with soft edge or narrow halo.

1. Particle size 30 to 45 millimicrons.

9. *Phagus major.*
10. *Phagus coli.*
11. *Phagus artus.*

E. Plaques very small, 0.1 to 1.2 mm in diameter, with sharp edges.

1. Particle size 50 to 75 millimicrons.

12. *Phagus maximus.*

II. Bacteriophages attacking *Agrobacterium tumefaciens* Conn, *Pseudomonas solanacearum* Smith, *Xanthomonas citri* Dowson, *Xanthomonas pruni* Dowson, *Erwinia carotovora* Holland, *Erwinia aroideae* Holland, *Bacterium stewarti* E. F. Smith.

A. Specific for bacterial hosts named above.

13. *Phagus tumoris.*
14. *Phagus solanacearum.*
15. *Phagus citri.*
16. *Phagus pruni.*
17. *Phagus deformans.*
18. *Phagus contumax.*
19. *Phagus maidis.*

III. Bacteriophages attacking *Salmonella enteritidis* Castellani and Chalmers.

20. *Phagus enteritidis.*
21. *Phagus commutabilis.*
22. *Phagus tertius.*
23. *Phagus dubius.*

IV. Bacteriophage attacking *Salmonella typhosa.*

24. *Phagus indicens.*

V. Bacteriophages attacking *Bacillus megatherium* DeBary, *Bacillus mycoides* Flügge, and *Rhizobium leguminosarum* Frank.

A. Thermal inactivation at 75° C in 10 minutes *in vitro.*

1. Host may be freed from bacteriophage by heating at 80° C for 10 minutes.

25. *Phagus testabilis.*

2. Host retains virus even when heated at 90° C for 10 minutes.

26. *Phagus indomitus.*

B. Thermal inactivation at 60° C in 30 minutes.

27. *Phagus subvertens.*

VI. Bacteriophages attacking streptococci.

28. *Phagus ineptus.*
29. *Phagus streptococci.*
30. *Phagus maculans.*
31. *Phagus lacerans.*
32. *Phagus tolerans.*
33. *Phagus michiganensis.*

VII. Bacteriophages attacking staphylococci.

34. *Phagus fragilis.*
35. *Phagus intermedius.*
36. *Phagus caducus.*
37. *Phagus alpha.*
38. *Phagus beta.*

39. *Phagus durabilis.*
40. *Phagus liber.*

VIII. Bacteriophages attacking vibrios.

41. *Phagus cholerae.*
42. *Phagus celer.*
43. *Phagus effrenus.*
44. *Phagus lentus.*

IX. Bacteriophages attacking *Corynebacterium diphtheriae* Lehmann and Neumann.

45. *Phagus diphtheriae.*
46. *Phagus futilis.*

1. **Phagus minimus** Holmes. (Handb. Phytopath. Viruses, 1939, 141.) From Latin *minimus*, least, in reference to size.

Common name: Bacteriophage S13.

Hosts: *Escherichia coli* Castellani and Chalmers; *Shigella dysenteriae* Castellani and Chalmers.

Induced disease: On plate cultures that are uniformly covered with confluent colonies of host organisms, this bacteriophage produces large cleared plaques, 8 to 12 mm in diameter, with wide shelving edges.

Serological relationships: No cross-neutralization reactions with bacteriophages C13, C36, D5, D20, C18, D3, S8, C21, C16, and D6.

Immunological relationships: Member of Resistance Group I.

Other properties: Particle size 8 to 12 millimicrons. Not affected by 26.3 per cent urea solution. Little or no inactivation by 1:25,000 methylene blue in 2 mm layer 20 cm from 100 candle-power light for 30 minutes. Lysis completely inhibited by 0.25 per cent solution of sodium citrate.

Literature: Burnet and McKie, Jour. Path. and Bact., *36*, 1933, 299–306, 307–318; *37*, 1933, 179–184; Burnet et al., Austral. Jour. Exp. Biol. and Med. Sci., *15*, 1937, 227–368.

2. **Phagus minor** H. (*loc. cit.*, 141). From Latin *minor*, lesser.

Common names: Bacteriophage C13, C8, and D44.

Hosts: *Escherichia coli* Castellani and Chalmers; *Shigella dysenteriae* Castellani and Chalmers.

Induced disease: Large plaques, 8 to 12 mm in diameter, with wide shelving edges.

Serological relationships: Cross reactions with bacteriophages C8 and D44 but not with bacteriophages S13, C36, D5, D20, D13, C18, D3, S8, C21, C16, D6.

Immunological relationships: Member of Resistance Group I.

Other properties: Particle size, 15 to 20 millimicrons. Completely inactivated by 1:25,000 methylene blue in 2 mm layer 20 cm from 100 candle-power light for 30 minutes. Specific soluble substance formed in lysed cultures blocks phage-antiphage reaction.

Literature: Burnet, Jour. Path. and Bact., *36*, 1933, 307–318; Brit. Jour. Exp. Path., *14*, 1933, 100–108.

3. **Phagus parvus** H. (*loc. cit.*, 142). From Latin *parvus*, small.

Common names: Bacteriophage C36, S18, C38, M, and C37 of Burnet.

Hosts: *Escherichia coli* Castellani and Chalmers; *Shigella dysenteriae* Castellani and Chalmers.

Induced disease: Moderately large plaques, 2 to 6 mm in diameter, with distinct halo.

Serological relationships: Induces formation of antibody capable of neutralizing bacteriophages S18, C38, M, and C37, but not bacteriophages S13, C13, D5, D20, D13, C18, D3, S8, C21, C16, or D6, which represent distinct serological groups.

Immunological relationships: Member of Resistance Group I.

Other properties: Particle size, 20 to 30 millimicrons. Completely inactivated by 1:25,000 methylene blue in 2 mm layer 20 cm from 100 candle-power light for 30 minutes.

Literature: Burnet, Jour. Path. and Bact., *36*, 1933, 307–318.

4. **Phagus primarius** H. (*loc. cit.*, 143). From Latin *primarius*, chief or first.

Common names: Bacteriophage D5, C51, C50, and D48.

Hosts: *Escherichia coli* Castellani and Chalmers; *Shigella dysenteriae* Castellani and Chalmers.

Induced disease: Moderately large plaques, 2 to 6 mm in diameter, with distinct halos.

Serological relationships: Cross-neutralization reactions with bacteriophages C51, C50, and D48, but not with S13, C13, C36, D20, D13, C18, D3, S8, C21, C16, D6.

Immunological relationships: Member of Resistance Group I.

Other properties: Particle size, 20 to 30 millimicrons. Completely inactivated by 1:25,000 methylene blue in 2 mm layer 20 cm from 100 candle-power light for 30 minutes.

Literature: Burnet, Jour. Path. and Bact., *36*, 1933, 307–318.

5. **Phagus secundarius** H. (*loc. cit.*, 143). From Latin *secundarius*, inferior or second.

Common names: Bacteriophage D20 and G.

Hosts: *Escherichia coli* Castellani and Chalmers; *Shigella dysenteriae* Castellani and Chalmers.

Induced disease: Moderately large plaques, 2 to 6 mm in diameter, with distinct halo.

Serological relationships: No cross-neutralization reactions with bacteriophages S13, C13, C36, D5, D13, C18, D3, S8, C21, C16, or D6.

Immunological relationships: Member of Resistance Group II.

Other properties: Nearly all inactivated by 1:25,000 methylene blue in 2 mm layer 20 cm from 100 candle-power light for 30 minutes. Particle size, 20 to 30 millimicrons.

Literature: Burnet, Jour. Path. and Bact., *36*, 1933, 307–318.

6. **Phagus dysenteriae** H. (*loc. cit.*, 144). From Latin *dysenteria*, dysentery.

Common names: Bacteriophage D13, specific dysentery phage.

Host: *Shigella dysenteriae* Castellani and Chalmers.

Insusceptible species: *Escherichia coli* Castellani and Chalmers.

Induced disease: Moderately large plaques, 2 to 6 mm in diameter, with distinct halo.

Serological relationships: Antiserum to this strain is not known to be effective against any other strain of bacteriophage; in particular, no cross reactions with bacteriophages S13, C13, C36, D5, D20, C18, D3, S8, C21, C16, or D6.

Immunological relationships: Member of Specific Dysentery Resistance Group.

Other properties: Particle size, 20 to 30 millimicrons. Completely inactivated by 1:25,000 methylene blue in 2 mm layer 20 cm from 100 candle-power light for 30 minutes.

Literature: Burnet, Jour. Path. and Bact., *36*, 1933, 307–318.

7. **Phagus medius** H. (*loc. cit.*, 144). From Latin *medius*, moderate, in reference to particle size.

Common name: Bacteriophage C18, C35, C26, C47, or C34.

Hosts: *Escherichia coli* Castellani and Chalmers; *Shigella dysenteriae* Castellani and Chalmers.

Induced disease: Medium size plaques, 1 to 3 mm in diameter, with distinct halo.

Serological relationships: Cross reactions with bacteriophages C35, C26, C47, and C34, but not with S13, C13, C36, D5, D20, D13, D3, S8, C21, C16, or D6.

Immunological relationships: Member of Resistance Group II.

Other properties: Particle size, 25 to 40 millimicrons.

Literature: Burnet, Jour. Path. and Bact., *36*, 1933, 307–318.

8. **Phagus astrictus** H. (*loc. cit.*, 145). From Latin *astrictus*, limited, in reference to inability to lyse *Escherichia coli* Castellani and Chalmers.

Common names: Bacteriophage D3; "smooth" dysentery phage.

Host: *Shigella dysenteriae* Castellani and Chalmers.

Insusceptible species: *Escherichia coli* Castellani and Chalmers.

Induced disease: Medium size plaques, 1 to 3 mm in diameter, with distinct halo.

Serological relationships: No cross-neutralization reactions with bacteriophages S13, C13, C36, D5, D20, D13, C18, S8, C21, C16, or D6.

Immunological relationships: Member of Smooth Dysentery Resistance Group.

Other properties: Particle size, 25 to 40 millimicrons. Nearly all inactivated by 1:25,000 methylene blue in 2 mm layer 20 cm from 100 candle-power light for 30 minutes.

Literature: Burnet, Jour. Path. and Bact., *36*, 1933, 307–318.

9. **Phagus major** H. (*loc. cit.*, 146). From Latin *major*, greater, in reference to particle size.

Common name: Bacteriophage S8, L, S28, C33, or S41.

Hosts: *Escherichia coli* Castellani and Chalmers; *Shigella dysenteriae* Castellani and Chalmers.

Induced disease: Small plaques, 0.5 to 1.5 mm in diameter, with soft edge or narrow halo.

Serological relationships: No cross-neutralization reactions with bacteriophages S13, C13, C36, D5, D20, D13, C18, D3, C21, C16, or D6.

Immunological relationships: Member of Resistance Group I.

Other properties: Particle size, 30 to 45 millimicrons.

Literature: Burnet, Jour. Path. and Bact., *36*, 1933, 307–318; Brit. Jour. Exp. Path., *14*, 1933, 100–108; Gough and Burnet, *ibid.*, *38*, 1934, 301–311.

10. **Phagus coli** H. (*loc. cit.*, 146). From Latin *colon*, the colon.

Common names: Bacteriophage C21 or C5; specific *coli* phage.

Host: *Escherichia coli* Castellani and Chalmers.

Insusceptible species: *Shigella dysenteriae* Castellani and Chalmers.

Induced disease: Small plaques, 0.5 to 1.5 mm in diameter, with soft edge or very narrow halo.

Serological relationships: No cross-neutralization with bacteriophages S13, C13, C36, D5, D20, D13, C18, D3, S8, C16, or D6.

Immunological relationships: Member of Specific *Escherichia coli* Resistance Group.

Other properties: Particle size, 30 to 45 millimicrons. Completely inactivated by 1:25,000 methylene blue in 2 mm layer 20 cm from 100 candle-power light for 30 minutes.

Literature: Burnet, Jour. Path. and Bact., *36*, 1933, 307–318.

11. **Phagus artus** H. (*loc. cit.*, 148). From Latin *artus*, narrow, in reference to limited host range.

Common names: Bacteriophage D6, D33; smooth dysentery phage.

Host: *Shigella dysenteriae* Castellani and Chalmers, smooth strains.

Induced disease: Small plaques, 0.5 to 1.5 mm in diameter, with soft edge or very narrow halo.

Serological relationships: Not neu-

tralized by sera specific for bacteriophages S13, C13, C36, D5, D20, D13, C18, D3, S8, C21, or C16.

Immunological relationships: Member of Smooth Dysentery Resistance Group.

Other properties: Particle size, 30 to 45 millimicrons.

Literature: Burnet, Jour. Path. and Bact., *36*, 1933, 307–318.

12. **Phagus maximus** H. (*loc. cit.*, 147). From Latin *maximus*, greatest, in reference to particle size.

Common names: Bacteriophage C16, C4, C15, C20, C32, C46, D4, D12, D29, D53, H, J, K, and W. L. L.

Hosts: *Escherichia coli* Castellani and Chalmers; *Shigella dysenteriae* Castellani and Chalmers.

Induced disease: Small plaques, 0.1 to 1.2 mm in diameter, with sharp edges.

Serological relationships: No cross-neutralization reaction with bacteriophages S13, C13, C36, D5, D20, D13, C18, D3, S8, C21, D6, or staphylococcus bacteriophage Au2. Agglutinated and inactivated by homologous, though not by other, antisera. For agglutination an original titer of 2×10^9 or higher is required; the reaction is visible to the unaided eye after 24 hours at 50° C and succeeds even after inactivation by heat (70 to 85° C for 30 minutes), formaldehyde, or a photodynamic dye (proflavine).

Immunological relationships: Member of Resistance Group II.

Thermal inactivation: At or below 70° to 85° C for 30 minutes.

Other properties: Particle size estimated by filtration as 50 to 75 millimicrons, by centrifuging as 79 to 90 millimicrons, from photographs as 50 to 60 millimicrons. Rapidly inactivated by 26.3 per cent urea solution. Little or no inactivation by 1:25,000 methylene blue in 2 mm layer 20 cm from 100 candle-power light for 30 minutes. Lysis not inhibited by 1.5 per cent or weaker solutions of sodium citrate. Thermolabile specific soluble substance formed in lysed cultures blocks phage-antiphage reaction.

Literature: Burnet, Brit. Jour. Exp. Path., *14*, 1933, 93–100, 100–108, 302–308; Jour. Path. and Bact., *36*, 1933, 307–318; *37*, 1933, 179–184; Burnet and Lush, *ibid.*, *40*, 1935, 455–469; Burnet and McKie, *ibid.*, *36*, 1933, 299–306.

13. **Phagus tumoris** H. (*loc. cit.*, 150). From Latin *tumor*, a swelling, in reference to association of this bacteriophage with bacterial tumors.

Common name: *Agrobacterium tumefaciens* bacteriophage.

Host: *Agrobacterium tumefaciens* Conn, most strains.

Insusceptible species: Some strains of *Agrobacterium tumefaciens*, *Bacterium stewarti* E. F. Smith, *Erwinia atroseptica* Bergey et al., *E. carotovora* Holland, *Pseudomonas tabaci* Stapp, *Xanthomonas beticola* Burkholder, *X. campestris* Dowson, *X. citri* Dowson, *X. phaseoli* Dowson *X. pruni* Dowson and *X. vesicatoria* Dowson.

Geographical distribution: United States, Russia.

Induced disease: Plaques 2 to 6 mm in diameter in 4 to 6 hours, edges of plaques spotted, moth-eaten in appearance until 40 hours after seeding; enlargement then stops and the edges of the plaques become smooth, double-ringed. Infection of plants by *Agrobacterium tumefaciens* is progressively inhibited by increasing amounts of bacteriophage in inoculum.

Thermal inactivation: At 95° C in 10 minutes (another report says 70° C, time not recorded).

Other properties: Resists dilution to $1:10^{11}$; storage at 5° C for over 25 months; prompt, though not gradual, drying; 1 per cent hydrogen peroxide for 72 hours; 95 per cent ethyl alcohol for 1 hour; 70 per cent ethyl alcohol for 6 hours; 2½ per cent phenol for 1 hour; 1:3000 nitric acid for 1 hour; N/64 sodium hydroxide for 1 hour.

Literature: Israilsky, Cent. f. Bakt.,

II Abt., *67*, 1926, 236–242; *71*, 1927, 302–311; *79*, 1929, 354–370; Kent, Phytopath., *27*, 1937, 871–902; Muncie and Patel, Phytopath., *20*, 1930, 289–305.

14. **Phagus solanacearum** H. (*loc. cit.*, 148). From name of host.

Common name: *Pseudomonas solanacearum* bacteriophage.

Host: *Pseudomonas solanacearum* Smith.

Geographical distribution: Formosa (Taiwan).

Induced disease: Medium size plaques on plate cultures of *Pseudomonas solanacearum.*

Serological relationships: When injected into rabbits, this bacteriophage stimulates the production of a specific precipitating antibody not giving cross reactions with anti-bacterial antibodies. Antiphagic serum inactivated at 90° C in 10 minutes.

Thermal inactivation: At 63° C in 10 minutes (61° C in 30 minutes; 66° C in about 1 minute).

Other properties: Optimum temperature for increase, 34° C.

Literature: Matsumoto and Okabe, Jour. Plant Prot., *22*, 1935, 15–20; Jour. Soc. Trop. Agr., *7*, 1935, 130–139; *9*, 1937, 205–213.

15. **Phagus citri** H. (*loc. cit.*, 149). From name of host.

Common name: *Xanthomonas citri* bacteriophage.

Host: *Xanthomonas citri* Dowson, the citrus canker organism.

Geographical distribution: Formosa (Taiwan).

Induced disease: Lysis. This bacteriophage has been isolated from soil under diseased trees, and once from infected leaves. It may play a role in the destruction of the citrus canker organism in the soil.

Other properties: Optimum temperature for increase, 30° C.

Literature: Matsumoto and Okabe, Agriculture and Horticulture, *12*, 1937, 2055–2059.

16. **Phagus pruni** H. (*loc. cit.*, 151). From name of host.

Common name: *Xanthomonas pruni* bacteriophage.

Host: *Xanthomonas pruni* Dowson.

Geographical distribution: United States (from soil beneath infected peach trees).

Induced disease: Lysis in broth cultures; plaques on agar cultures, but characteristics of plaques not described.

Other properties: Estimated diameter 11 millimicrons in broth. Resists dilution to $1:10^6$ or more.

Literature: Anderson, Phytopath., *18*, 1928, 144; Thornberry, *ibid.*, *25*, 1935, 938–946.

17. **Phagus deformans** H. (*loc. cit.*, 151). From Latin *deformare*, to disfigure, in reference to malformation of infected host cells.

Common name: *Erwinia carotovora* bacteriophage.

Host: *Erwinia carotovora* Holland.

Insusceptible species: *Agrobacterium tumefaciens* Conn, except in some early tests with possibly mixed bacteriophages; *Erwinia amylovora* Winslow et al., *E. melonis* Holland, *Salmonella pullorum* Bergery et al., *S. gallinarum* Bergey et al., Shigella dysenteriae Castellani and Chalmers, *Xanthomonas pruni* Dowson.

Geographical distribution: United States (Michigan).

Induced disease: In *Erwinia carotovora*, cells reduced in motility, agglutinated, malformed, some elongated, others swollen, bulged at one end, bulged in middle, or enlarged and spherical.

Other properties: Resists dilution to $1:10^9$, and storage in sterile medium at room temperature for 5½ months.

Literature: Coons and Kotila, Phytopath., *15*, 1925, 357–370; Mallmann and Hemstreet, Jour. Agr. Res., *28*, 1924, 599–602.

18. **Phagus contumax** *spec. nov.* From Latin *contumax*, refractory, in reference to ability of this bacteriophage to withstand heating sufficient to destroy accompanying host cells.

Common name: *Erwinia aroideae* bacteriophage.

Host: *Erwinia aroideae* Holland.

Insusceptible species: *Agrobacterium tumefaciens* Conn, *Bacterium formosanum* Okabe, *Erwinia carotovora* Holland, *Pseudomonas andropogoni* Stapp, *P. solanacearum* Smith, *P. tomato* Burkholder, *Xanthomonas campestris* Dowson, *X. citri* Dowson, *X. malvacearum* Dowson, *X. nakatae* Dowson, *X. phaseoli* Dowson, *X. ricinicola* Dowson.

Geographical distribution: Formosa (Taiwan).

Induced disease: Very small plaques, 0.1 to 1.0 mm (mostly less than 0.5 mm) in diameter.

Thermal inactivation: Resists heating at 60° C for 30 minutes without appreciable loss of titer, but host organism is killed by this treatment.

Other properties: Optimum temperature for increase, about 25° C. This bacteriophage may be prepared by heating centrifuged cultures at 60° C for 30 minutes as efficiently as by filtration to remove bacteria.

Literature: Matsumoto, Trans. Nat. Hist. Soc. Formosa, *29*, 1939, 317–338; *30*, 1940, 89–98; *31*, 1941, 145–154; Matsumoto and Sawada, *ibid.*, *28*, 1938, 247–256.

19. **Phagus maidis** H. (*loc. cit.*, 152). From New Latin *mais*, corn (maize), host of *Bacterium stewarti*.

Common name: *Bacterium stewarti* bacteriophage; *Phytomonas stewarti* bacteriophage; *Aplanobacter stewarti* bacteriophage.

Host: *Bacterium stewarti* E. F. Smith (= *Pseudomonas stewarti* E. F. Smith, *Phytomonas stewarti* Bergey et al. and *Aplanobacter stewarti* McCulloch).

Geographical distribution: United States.

Induced disease: In *Bacterium stewarti*, variation or loss of yellow color, change of viscosity of growth, reduction or loss of virulence. Infection of corn plants by seed-borne *Bacterium stewarti* is much reduced by treating seeds with this bacteriophage before they are planted.

Thermal inactivation: Above 65° C in 30 minutes.

Other properties: Infective in dilutions to 10^{-7}. Soon lost from cultures maintained at pH 3.85 to 4.00, or on Ivanoff's medium, which contains oxidizing compounds.

Literature: Thomas, Phytopath., *25*, 1935, 371–372; Science, *88*, 1938, 56–57; Phytopath., *30*, 1940, 602–611.

20. **Phagus enteritidis** H. (*loc. cit.*, 153). From name of host.

Common names: *Salmonella enteritidis* bacteriophage 1, 12, or 33; Group A bacteriophages.

Hosts: *Salmonella enteritidis* Castellani and Chalmers, *S. gallinarum* Bergey et al., *Shigella dysenteriae* Castellani and Chalmers.

Induced disease: Plaques of medium size, usually with surrounding translucent halo.

Immunological relationships: Member of Resistance Group A; host individuals that have acquired resistance to this bacteriophage are resistant to lines 12 and 33, but susceptible to *Salmonella enteritidis* bacteriophages 8, 20, and 11, as well as to other strains of Resistance Groups B, C, and D.

Literature: Burnet, Jour. Path. and Bact., *32*, 1929, 15–42.

21. **Phagus commutabilis** H. (*loc. cit.*, 153). From Latin *commutabilis*, variable, in reference to differences within Resistance Group B, typified by this bacteriophage.

Common names: *Salmonella enteritidis* bacteriophage 8, 18, 28, 31, 34, 38; Group B bacteriophages.

Hosts: *Salmonella enteritidis* Castellani

and Chalmers, *Shigella dysenteriae* Castellani and Chalmers, *Shigella gallinarum* Weldin, *Salmonella typhosa* White.

Induced disease: Small plaques with sharp edges, or moderately large plaques with characteristic halo.

Immunological relationships: Member of Resistance Group B; host individuals that have acquired resistance to this bacteriophage are resistant to lines 18, 28, 31, 34, and 38, but susceptible to *Salmonella enteritidis* bacteriophages 1, 20, and 11, as well as to other strains of Resistance Groups A, C, and D.

Literature: Burnet, Jour. Path. and Bact., *32*, 1929, 15–42.

22. **Phagus tertius** H. (*loc. cit.*, 154). From Latin *tertius*, third, in reference to the third Resistance Group of *Salmonella enteritidis* bacteriophages, Group C, typified by this bacteriophage.

Common names: *Salmonella enteritidis* bacteriophage 20, 25, 32, 35; Group C bacteriophages.

Hosts: *Salmonella enteritidis* Castellani and Chalmers, *S. gallinarum* Bergey et al., *Shigella dysenteriae* Castellani and Chalmers.

Induced disease: Plaques of small size, with sharp edges.

Immunological relationships: Member of Resistance Group C. Host individuals that have acquired resistance to this bacteriophage are resistant to lines 25, 35, and 32, but susceptible to *Salmonella enteritidis* bacteriophages of Resistance Groups A, B, and D.

Literature: Burnet, Jour. Path. and Bact., *32*, 1929, 15–42.

23. **Phagus dubius** H. (*loc. cit.*, 155). From Latin *dubius*, doubtful, in reference to uncertainty of distinction between Resistance Groups C and D.

Common names: *Salmonella enteritidis* bacteriophage 11, 13; Group D bacteriophages.

Hosts: *Salmonella enteritidis* Castellani and Chalmers, *Shigella dysenteriae* Castellani and Chalmers, *Shigella gallinarum* Weldin.

Induced disease: Very large plaques, up to 8 mm in diameter on 1.2 per cent agar.

Immunological relationships: Member of Resistance Group D. Host individuals that have acquired resistance to this bacteriophage are resistant to line 13, but susceptible to *Salmonella enteritidis* bacteriophages of Resistance Groups A, B, and C.

Literature: Burnet, Jour. Path. and Bact., *32*, 1929, 15–42.

24. **Phagus indicens** *spec. nov.* From Latin *indicere*, to disclose or indicate, in reference to diagnostic use of this bacteriophage in identifying V forms of the typhoid bacillus.

Common name: Phage Q151.

Host: *Salmonella typhosa* White (= *Bacillus typhosus* Zopf).

Insusceptible species: W forms of the typhoid organism and various *Salmonella* species.

Geographical distribution: Canada.

Induced disease: In *Salmonella typhosa*, small plaque formation (lysis) and complete inhibition of growth in cultures of the V form (bearing Vi antigen; resisting O agglutination) and no lysis or restraining effect on growth of the W form (lacking Vi antigen; agglutinated by O antiserum). In the presence of the virus, mixed cultures are quickly transformed since only W variants can increase. Pure V cultures can be identified by the test for their complete inhibition; this inhibition is regularly followed by secondary growth representing the pure W form of the host, a readily formed variant.

Filterability: Passes Seitz EK filter.

Other properties: Filtrates active in dilutions to 10^{-9} or 10^{-11}.

Literature: Craigie, Jour. Bact., *31*, 1936, 56 (Abst.); Craigie and Brandon, Jour. Path. and Bact., *43*, 1936, 233–248, 249–260.

25. **Phagus testabilis** H. (*loc. cit.*, 155). From Latin *testabilis*, able to bear witness, in reference to evidence that this bacteriophage has given, by virtue of its easy destruction when heated in spores, against the hypothesis of frequent spontaneous origin of bacteriophage from the bacterial host.

Common name: *Bacillus megatherium* bacteriophage.

Host: *Bacillus megatherium* De Bary.

Geographical distribution: United States.

Induced disease: Plaques 0.5 mm or less in diameter, with surrounding translucent zone.

Thermal inactivation: *In vitro*, at 75° C in 10 minutes. Spores from infected cultures, after being heated for 10 minutes at 80° C, regularly give rise to subcultures that do not show the presence of this bacteriophage spontaneously during subsequent growth but that are susceptible to lysis if the bacteriophage is again introduced.

Literature: Adant, Compt. rend. Soc. Biol., Paris, *99*, 1928, 1246; Cowles, Jour. Bact., *20*, 1930, 15–23.

26. **Phagus indomitus** H. (*loc. cit.*, 156). From Latin *indomitus*, unrestrained, in reference to the ability of this bacteriophage to increase after heat treatment of infected spores.

Common name: *Bacillus mycoides* bacteriophage.

Host: *Bacillus mycoides* Flügge, some strains.

Insusceptible species: *Bacillus cereus* Frankland and Frankland, *B. subtilis* Cohn emend. Prazmowski, *B. megatherium* De Bary, *B. anthracis* Cohn emend. Koch. Some strains of *B. mycoides*.

Geographical distribution. United States.

Induced disease: Large plaques, with some secondary growth of host organism.

Thermal inactivation: *In vitro*, at 75° C in 10 minutes. Spores from infected cultures, heated at 90° C for 10 minutes give no bacteriophage on grinding, but lytic cultures when grown.

Literature: Lewis and Worley, Jour. Bact., *32*, 1936, 195–198.

27. **Phagus subvertens** H. (*loc. cit.*, 156). From Latin *subvertere*, to subvert, in reference to suspected action of this bacteriophage in causing running-out of alfalfa fields through destruction of nodule organisms.

Common name: *Rhizobium leguminosarum* bacteriophage.

Host: *Rhizobium leguminosarum* Frank. It has been shown that this bacteriophage is unable to increase in clover roots without the nodule-forming organism, *R. leguminosarum*, and that the bacteriophage plays no obviously essential role in nodule formation.

Induced disease: Very small plaques, with edges not sharply defined.

Thermal inactivation: At 60° C in 30 minutes.

Other properties: Not inactivated by drying for 2 months.

Literature: Gerretsen et al., Cent. f. Bakt., II Abt., *60*, 1923, 311–316; Grijns, *ibid.*, *71*, 1927, 248–251; Hitchner, Jour. Bact., *19*, 1930, 191–201; Vandecaveye and Katznelson, Jour. Bact., *31*, 1936, 465–477.

28. **Phagus ineptus** H. (*loc. cit.*, 157). From Latin *ineptus*, unsuitable, in reference to inability of this bacteriophage to adapt itself to lysis of strain RW of its host.

Common name: Streptococcus bacteriophage R.

Host: *Streptococcus cremoris* Orla-Jensen, strain R.

Insusceptible species: *Streptococcus cremoris*, strain RW.

Geographical distribution: New Zealand.

Induced disease: Plaques 0.25 to 0.6 mm in diameter.

Serological relationships: Antisera specific for streptococcus bacteriophage RW

and its strain RW1 are ineffective in neutralizing this bacteriophage.

Immunological relationships: Cultures of host-strain R, after exposure to this bacteriophage, furnish subcultures only partly resistant to this bacteriophage and completely susceptible to streptococcus bacteriophage RW and its substrain RW1.

Literature: Whitehead and Hunter, Jour. Path. and Bact., *44*, 1937, 337–347.

29. **Phagus streptococci** H. (*loc. cit.*, 158). From generic name of host.

Common name: Streptococcus bacteriophage RW.

Host: *Streptococcus cremoris* Orla-Jensen, strain RW.

Geographical distribution: New Zealand.

Induced disease: Plaques 0.25 to 0.6 mm in diameter.

Thermal inactivation: At 70° to 75° C, time not recorded, probably 30 minutes (pH 6.0).

Literature: Whitehead and Hunter, Jour. Path. and Bact., *44*, 1937, 337–347.

Strains: One variant has been described and distinguished from the type variety, *typicus* H. (*loc. cit.*, 158):

29a. *Phagus streptococci* var. *virilis* H. (*loc. cit.*, 158). From Latin *virilis*, vigorous. Common name: Strain RW1 of streptococcus bacteriophage RW. Differing from the type variety in being able to increase at the expense of strain RW1 of *Streptococcus cremoris* (Whitehead and Hunter, Jour. Path. and Bact., *44*, 1937, 337–347).

30. **Phagus maculans** *spec. nov.* From Latin *maculare*, to speckle, in reference to tiny plaques produced by this bacteriophage.

Common name: Streptococcus bacteriophage A.

Hosts: Streptococcus 646, 751, 775.

Geographical distribution: United States (Massachusetts).

Induced disease: Plaques exceedingly minute, scarcely visible to the unaided eye.

Serological relationships: Specific antisera neutralize but there is no cross reaction with respect to streptococcus bacteriophage B, C, or D.

Thermal inactivation: At 60° C in 1 hour.

Other properties: Withstands storage at about 5° C for at least 145 days with but little loss of virulence.

Literature: Evans, Science, *80*, 1934, 40–41; U.S.P.H.S., Public Health Reports, *49*, 1934, 1386–1401.

31. **Phagus lacerans** *spec. nov.* From Latin *lacerare*, to tear, in reference to ragged edges of plaques produced by this bacteriophage.

Common name: Streptococcus bacteriophage B.

Hosts: Streptococcus 563,639: *Streptococcus mucosus* Howard and Perkins.

Insusceptible species: *Streptococcus erysipelatos* Rosenbach.

Geographical distribution: United States (Wisconsin).

Induced disease: Medium size plaques, the largest about 3 mm in diameter, edges ragged, centers clean.

Serological relationships: Specific neutralization, but no cross reactions with streptococcus bacteriophages A, C, and D.

Thermal inactivation: At 60° C in 1 hour.

Other properties: Withstands storage at about 5° C for at least 261 days.

Literature: Clark and Clark, Jour. Bact., *11*, 1926, 89; Proc. Soc. Exp. Biol. and Med., *24*, 1927, 635–639; Colvin, Jour. Inf. Dis., *51*, 1932, 17–29; Evans, U.S.P.H.S., Public Health Reports, *49*, 1934, 1386–1401; Jour. Bact., *39*, 1940, 597–604; Shwartzman, Jour. Exp. Med., *46*, 1927, 497–509.

32. **Phagus tolerans** *spec. nov.* From Latin *tolerans*, tolerating, in reference to the unusual ability of this streptococcus

bacteriophage to remain viable under certain adverse conditions.

Common name: Streptococcus bacteriophage C.

Hosts: Streptococcus 646, 594, 756, 806.

Geographical distribution: United States (Ohio, Massachusetts, Connecticut).

Induced disease: Small plaques, the largest about 1.0 mm in diameter.

Serological relationships: Specific neutralization, but no cross reactions with streptococcus bacteriophages A, B, and D.

Thermal inactivation: At 63° to 65° C in 1 hour.

Other properties: Withstands storage in 1:200 phenol at about 5° C for at least 261 days; equally resistant to storage in 1:10,000 sodium ethyl mercurithiosalicylate (merthiolate), or to storage without preservatives.

Literature: Evans, U. S. Pub. Health Ser., Public Health Reports, *49*, 1934, 1386–1401.

33. **Phagus michiganensis** *spec. nov.* From name of state, Michigan, where this bacteriophage was first isolated.

Common name: Streptococcus bacteriophage D.

Host: Streptococcus 693.

Geographical distribution: United States (Michigan).

Induced disease: Small plaques, about 0.75 mm in diameter, edges clear-cut, centers clean.

Serological relationships: Specific neutralization, but no cross neutralization with streptococcus bacteriophages A, B, and C.

Thermal inactivation: At 60° to 63° C in 1 hour.

Other properties: Withstands storage at about 5°C for at least 261 days.

Literature: Evans, U. S. Pub. Health Ser., Public Health Reports, *49*, 1934, 1386–1401.

34. **Phagus fragilis**, H. (*loc. cit.*, 159). From Latin *fragilis*, fragile, in reference to easy destruction of this bacteriophage by light and by concentrated urea solutions.

Common names: Staphylococcus bacteriophage Au2, Au3, Au4, or D, perhaps bacteriophage H of Gratia.

Hosts: *Staphylococcus aureus* Rosenbach and *Staphylococcus albus* Rosenbach.

Geographical distribution: United States.

Induced disease: Small plaques, 0.2 to 1.0 mm in diameter, with sharp edges.

Serological relationships: Cross-neutralization reactions with staphylococcus bacteriophages Au1, Au3, Au4, and D, but not with staphylococcus bacteriophages Au21, Au12, A, B, C, or bacteriophage C16.

Thermal inactivation: At about 57° C in 30 minutes.

Other properties: Particle diameter 50 to 75 millimicrons. Readily inactivated photodynamically. Completely inactivated by 27 per cent urea solution in 1 hour at 37° C. Lysis not inhibited even by 1.5 per cent sodium citrate in agar medium.

Literature: Burnet and Lush, Jour. Path. and Bact., *40*, 1935, 455–469; Burnet and McKie, Austral. Jour. Exp. Biol. and Med. Sci., *6*, 1929, 21–31; Fisk, Jour. Inf. Dis., *71*, 1942, 153–160.

35. **Phagus intermedius** H. (*loc. cit.*, 160). From Latin *intermedius*, intermediate, in reference to position of this bacteriophage between staphylococcus bacteriophages that multiply readily in broth cultures of host organisms and those that do not.

Common name: Staphylococcus bacteriophage Au21.

Host: *Staphylococcus aureus* Rosenbach.

Geographical distribution: Australia.

Induced disease: Small plaques, 0.1 to 0.3 mm in diameter, with sharp edges.

Serological relationships: Specific neutralization reaction but no cross-neutralization reaction with staphylococcus bacteriophages Au2 or Au12.

Other properties: Not readily inactivated photodynamically; completely inactivated by 27 per cent urea solution in 1 hour at 37° C; lysis inhibited by 1 per cent sodium citrate in agar medium but not by 0.5 per cent or lower concentrations.

Literature: Burnet and Lush, Jour. Path. and Bact., *40*, 1935, 455–469.

36. **Phagus caducus** H. (*loc. cit.*, 160). From Latin *caducus*, perishable, in reference to the easy destruction of this bacteriophage by concentrated urea solutions.

Common name: Staphylococcus bacteriophage Au12.

Host: *Staphylococcus aureus* Rosenbach.

Geographical distribution: Australia.

Induced disease: Small plaques, 0.2 to 0.5 mm in diameter, with sharp edges.

Serological relationships: Cross-neutralization reactions with staphylococcus bacteriophages Au11 and Au13, but not with staphylococcus bacteriophages Au2, Au21, A, and C. Antiserum to staphylococcus bacteriophage B gives no neutralization of Au12, though the reciprocal reaction occurs to 1:200 dilution.

Other properties: Not readily inactivated photodynamically; completely inactivated by 27 per cent urea solution in 1 hour at 37° C; lysis inhibited by as little as 0.25 per cent sodium citrate in agar.

Literature: Burnet and Lush, Jour. Path. and Bact., *40*, 1935, 455–469.

37. **Phagus alpha** H. (*loc. cit.*, 161). From Greek equivalent of common name.

Common name: Staphylococcus bacteriophage A.

Host: *Staphylococcus albus* Rosenbach.

Geographical distribution: Australia.

Induced disease: Plaques of medium size, 1.5 to 2.5 mm in diameter, with hazy periphery.

Serological relationships: Specific neutralization reaction, but no cross-neutralization reactions with staphylococcus bacteriophages Au2, B, or C.

Immunological relationships: Colonies of *Staphylococcus albus* appearing after lysis with this bacteriophage are resistant to staphylococcus bacteriophages B, C, and D.

Thermal inactivation: At 68° to 70° C in 30 minutes.

Other properties: Not readily inactivated photodynamically; not completely inactivated by 27 per cent urea solution in 1 hour at 37° C; lysis not inhibited even by 1.5 per cent sodium citrate in agar.

Literature: Burnet and Lush, Jour. Path. and Bact., *40*, 1935, 455–469; Burnet and McKie, Austral. Jour. Exp. Biol. and Med. Sci., *6*, 1929, 21–31.

38. **Phagus beta** H. (*loc. cit.*, 162). From Greek equivalent of common name.

Common name: Staphylococcus bacteriophage B.

Host: *Staphylococcus albus* Rosenbach.

Geographical distribution: Australia.

Induced disease: Plaques of medium size, 0.7 to 1.5 mm in diameter, with sharp edges.

Serological relationships: Specific neutralization reaction, but no cross-neutralization reaction with respect to staphylococcus bacteriophages Au2, Au12, A, or C, except that antiserum made with Au12 neutralizes this bacteriophage in low dilutions (See *Phagus caducus*).

Immunological relationships: Colonies appearing after lysis of *Staphylococcus albus* with this bacteriophage furnish organisms susceptible to staphylococcus bacteriophages A and D.

Thermal inactivation: At 63° to 65° C in 10 minutes.

Other properties: Readily inactivated photodynamically; completely inactivated by 27 per cent urea solution in 1 hour at 37° C; lysis not inhibited even by 1.5 per cent sodium citrate in agar medium.

Literature: Burnet and Lush, Jour. Path. and Bact., *40*, 1935, 455–469; Burnet

and McKie, Austral. Jour. Exp. Biol. and Med. Sci., *6*, 1929, 21–31.

39. **Phagus durabilis** H. (*loc. cit.*, 162). From Latin *durabilis*, lasting, in reference to the stability of this bacteriophage in concentrated urea solution and other unfavorable media.

Common name: Staphylococcus bacteriophage C.

Host: *Staphylococcus albus* Rosenbach.

Geographical distribution: Australia.

Induced disease: Plaques 2.0 to 3.0 mm in diameter. Vitreous change in peripheral zone.

Serological relationships: Cross-neutralization reaction with staphylococcus bacteriophage C′, and less strongly with B, but not with Au2 or A.

Immunological relationships: Colonies of *Staphylococcus albus* appearing after lysis with this bacteriophage furnish organisms resistant to it but susceptible to staphylococcus bacteriophages A, B, and D.

Thermal inactivation: At 61° to 63° C in 30 minutes.

Other properties: Not readily inactivated photodynamically; not completely inactivated by 27 per cent urea solution in 1 hour at 37° C; lysis not inhibited even by 1.5 per cent sodium citrate in agar medium.

Literature: Burnet and Lush, Jour. Path. and Bact., *40*, 1935, 455–469; Burnet and McKie, Austral. Jour. Exp. Biol. and Med. Sci., *6*, 1929, 21–31; Rakieten et al., Jour. Bact., *32*, 1936, 505–518.

40. **Phagus liber** H. (*loc. cit.*, 163). From Latin *liber*, independent, in reference to demonstrated independence of this virus, its bacterial host, and its dipterous superhost, in respect to origin.

Common name: *Staphylococcus muscae* bacteriophage.

Host: *Staphylococcus muscae* Glaser.

Geographical distribution: United States.

Induced disease: Lysis in broth cultures; plaques in agar cultures, but characteristics of plaques not recorded.

Thermal inactivation: At a little above 50° C in 5 minutes.

Other properties: A characteristic nucleoprotein has been isolated from lysed staphylococci. Sedimentation constant, 650 × 10^{-13} cm $dyne^{-1}$ $sec.^{-1}$, corresponding to a molecular weight of about 300,000,000. Denatured at acidities beyond pH 5.0. Digested by chymotrypsin, not by trypsin. Apparent density, about 1.20. Diffusion coefficient, varying with dilution.

Literature: Glaser, Amer. Jour. Hygiene, *27*, 1938, 311–315; Northrop, Jour. Gen. Physiol., *21*, 1938, 335–366; Shope, Jour. Exp. Med., *45*, 1927, 1037–1044; Wyckoff, Jour. Gen. Physiol., *21*, 1938, 367–373.

41. **Phagus cholerae** H. (*loc. cit.*, 164). From former name of host.

Common name: *Vibrio comma* bacteriophage.

Host: *Vibrio comma* Winslow et al. (formerly *V. cholerae* Neisser); Indian strains usually carry this bacteriophage, but Chinese and Japanese strains lack it, are susceptible, and upon inoculation become lysogenic.

Geographical distribution: India.

Induced disease: In both R and S forms of *Vibrio comma*, no plaques on ordinary agar plates, but vibrios become lysogenic. Egg-white in 1:25 dilution enhances activity enough to allow visible lysis, occasional plaques, or stippling at the site of inoculation.

Immunological relationships: *Vibrio comma* organisms that have been infected with this bacteriophage and are resistant to its further action are still susceptible to cholera bacteriophages A, C, and D.

Literature: White, Jour. Path. and Bact., *44*, 1937, 276–278.

42. **Phagus celer** H. (*loc. cit.*, 164). From Latin *celer*, quick, in reference to relatively quick action of this bacteriophage.

Common name: Cholera bacteriophage A.

Host: *Vibrio comma* Winslow et al., smooth types, except non-agglutinable vibrios.

Geographical distribution: India.

Induced disease: Lysis in 2 hours, followed by abundant secondary growth. Only smooth elements of the culture are attacked.

Serological relationships: Antigenically distinct from cholera bacteriophage C.

Immunological relationships: Secondary growth resistant to this virus, but susceptible to cholera bacteriophages C and D.

Other properties: Selectively inactivated by specific polysaccharide of smooth strains, not by a lipoid emulsion that is effective against cholera bacteriophage C. Active in dilution of $1:10^9$ or $1:10^{10}$. Multiplication rate, $n \times 10^5$ in 2 hours.

Literature: Asheshov et al., Indian Jour. Med. Res., *20*, 1933, 1127–1157; White, Jour. Path. and Bact., *43*, 1936, 591–593.

43. **Phagus effrenus** H. (*loc. cit.*, 165). From Latin *effrenus*, unbridled, in reference to the ability of this bacteriophage to attack all tested strains of the cholera organism.

Common name: Cholera bacteriophage C.

Host: *Vibrio comma* Winslow et al., all strains.

Geographical distribution: India.

Induced disease: Sometimes death without lysis. When lysis occurs, it is rarely complete and is followed by secondary resistant growth.

Serological relationships: Antigenically distinct from cholera bacteriophage A.

Immunological relationships: Secondary growth resistant to this bacteriophage, but susceptible to cholera bacteriophages A and D.

Other properties: Selectively inactivated by lipoid from smooth strain of host, but not by specific polysaccharide. Active in dilution of $1:10^8$ or $1:10^{10}$. Multiplication rate, $n \times 10^1$ in 2 hours.

Literature: Asheshov et al., Indian Jour. Med. Res., *20*, 1933, 1127–1157; White, Jour. Path. and Bact., *43*, 1936, 591–593.

44. **Phagus lentus** H. (*loc. cit.*, 166). From Latin *lentus*, slow, in reference to the relatively slow and incomplete lysis induced by this bacteriophage.

Common name: Cholera bacteriophage D.

Host: *Vibrio comma* Winslow et al.

Geographical distribution: India.

Induced disease: Incomplete lysis in about 5 hours, followed, in rough cultures, by slow development of resistant secondary growth.

Immunological relationships: Secondary growth resistant to this bacteriophage, but susceptible to cholera bacteriophages A and C.

Other properties: Not inactivated by specific polysaccharide effective against cholera bacteriophage A, nor by lipoid effective against cholera bacteriophage C. Multiplication rate, $n \times 10^2$ in 2 hours.

Literature: Asheshov et al., Indian Jour. Med. Res., *20*, 1933, 1127–1157; White, Jour. Path. and Bact., *43*, 1936, 591–593.

45. **Phagus diphtheriae** H. (*loc. cit.*, 167). From name of host.

Common name: *Corynebacterium diphtheriae* bacteriophage.

Host: *Corynebacterium diphtheriae* Lehmann and Neumann, many strains, especially 122 of 127 Australian type II *gravis* isolates; type I *gravis* isolates are lysogenic (carriers); all intermediate isolates are susceptible.

Insusceptible species: *Corynebacterium diphtheriae*, all tested *mitis* isolates, except 2 lysogenic. A strain of *C. diphtheriae* from Swan Hill, 200 miles north of Melbourne, was found to be resistant to this bacteriophage and to the small-

plaque diphtheria bacteriophage, *P. futilis*.

Geographical distribution: Australia.

Induced disease: In *Corynebacterium diphtheriae* on agar, plaques 1.0 to 1.5 mm in diameter, with shelving edge. A few resistant bacterial colonies often appear in the central clear area.

Literature: Keogh et al., Jour. Path. and Bact., *46*, 1938, 565–570; Smith and Jordan, Jour. Bact., *21*, 1931, 75–88; Stone and Hobby, Jour. Bact., *27*, 1934, 403–417.

46. **Phagus futilis** H. (*loc. cit.*, 168). From Latin *futilis*, vain, in reference to regular appearance of resistant organisms in plaques on agar cultures lysed by this bacteriophage.

Common name: Small-plaque diphtheria bacteriophage.

Host: *Corynebacterium diphtheriae* Lehmann and Neumann, *gravis* type I isolates and all but 5 *gravis* type II isolates.

Insusceptible species: All tested intermediate and *mitis* strains of *C. diphtheriae*.

Geographical distribution: Australia.

Induced disease: In *Corynebacterium diphtheriae* on agar, pin-point plaques or confluent plaques, with confluent growth of secondary, resistant organisms.

Literature: Keogh et al., Jour. Path. and Bact., *46*, 1938, 565–570.

Suborder II. **Phytophagineae** *subordo novus.*

Viruses infecting higher plants; vectors typically homopterous or hemipterous insects (leafhoppers, aphids, white flies, true bugs) or thysanopterous insects (thrips). From Greek *phagein*, to eat, and *phyton*, a plant.

Key to the families of suborder **Phytophagineae.**

1. Inducing yellows-type diseases; vectors typically cicadellid or fulgorid leafhoppers.
   Family I. *Chlorogenaceae*, p. 1145.
2. Inducing mosaic diseases; vectors typically aphids.
   Family II. *Marmoraceae*, p.1163.
3. Inducing ringspot diseases; vectors unknown.
   Family III. *Annulaceae*, p. 1212.
4. Inducing leaf-curl diseases; vectors typically white flies.
   Family IV. *Rugaceae*, p. 1218.
5. Inducing leaf-savoying diseases; vectors, true bugs.
   Family V. *Savoiaceae*, p. 1221.
6. Inducing spotted wilt; vectors, thrips.
   Family VI. *Lethaceae*, p. 1223.

FAMILY I. CHLOROGENACEAE HOLMES EMEND.

(Handb. Phytopath. Viruses, 1939, 1.)

Viruses of the Yellows-Disease Group; pathogenic in flowering plants, causing diseases in which effects on chlorophyll are usually diffuse or stripe-like, no typical spotting or spotty mottling being involved. Vectors, so far as known, leafhoppers (*CICADELLIDAE* and *FULGORIDAE*).

Key to the genera of family **Chlorogenaceae.**

I. True Yellows Group. Viruses inducing diseases usually characterized by stimulation of normally dormant and adventitious buds to produce numerous slender shoots with long internodes and by chlorosis without spotting; invaded parts abnormally erect in habit. Vectors cicadellid leafhoppers so far as known.
   Genus I. *Chlorogenus*, p. 1146.

II. Peach X-Disease Group. Viruses inducing diseases characterized by rosetting of foliage and sometimes death of host.
   Genus II. *Carpophthora*, p. 1151.

III. Phloem-Necrosis Group. Viruses inducing diseases characterized by progressive degeneration of the host plant or by wilting and sudden death; sometimes by root discoloration. Vectors cicadellid leafhoppers so far as known.
   Genus III. *Morsus*, p. 1153.

IV. Yellow-Dwarf Group. Viruses inducing diseases characterized by chlorotic effects somewhat resembling true mottling but often more diffuse. Vectors cicadellid (agallian) leafhoppers.
   Genus IV. *Aureogenus*, p. 1154.

V. Fiji-Disease Group. Viruses inducing diseases characterized by marked vascular proliferation. The vector of one is known to be a leafhopper of the subfamily Delphacinae, family *FULGORIDAE*.
   Genus V. *Galla*, p. 1157.

VI. Stripe-Disease Group. Viruses inducing diseases characterized by chlorotic striping; hosts grasses. Vectors, cicadellid and fulgorid leafhoppers.
Genus VI. *Fractilinea*, p. 1159.

Genus I. **Chlorogenus** *Holmes.*

(*Loc. cit.*, 1.)

Viruses of the Typical Yellows Group, inducing diseases usually characterized by stimulation of normally dormant and adventitious buds to produce numerous slender shoots with long internodes, by chlorosis without spotting, or by both growth of numerous slender shoots and chlorosis. Invaded parts abnormally erect in habit. Affected flowers often virescent. Hosts, dicotyledonous plants. Vectors, so far as known, exclusively cicadellid leafhoppers. Generic name from Greek *chloros*, light green or yellow, and suffix, *gen*, signifying producing, from Greek *genos*, descent.

The type species is *Chlorogenus callistephi* Holmes.

Key to the species of genus **Chlorogenus.**

I. Natural hosts many, in various families of plants.
1. *Chlorogenus callistephi.*
2. *Chlorogenus australiensis.*

II. Known natural hosts relatively few.
A. Natural hosts rosaceous.
3. *Chlorogenus persicae.*
B. Natural hosts solanaceous.
4. *Chlorogenus solani.*
C. Natural host sandal.
5. *Chlorogenus santali.*
D. Natural host cranberry.
6. *Chlorogenus vaccinii.*
E. Natural host locust.
7. *Chlorogenus robiniae.*
F. Natural host alfalfa.
8. *Chlorogenus medicaginis.*
G. Natural host hop.
9. *Chlorogenus humuli.*

1. **Chlorogenus callistephi** Holmes. (Handb. Phytopath. Viruses, 1939, 2.) From New Latin *Callistephus*, generic name of the China aster.

Common names: Aster-yellows virus, lettuce white-heart virus, *Erigeron*-yellows virus.

Hosts: *Callistephus chinensis* Nees, the China aster, is the host that has been studied most. 170 or more species in 38 different families of dicotyledonous plants have been shown susceptible. Lettuce, endive, carrot, buckwheat, parsnip, and New Zealand spinach are among the hosts of economic importance.

Insusceptible species: All tested species of the family *Leguminosae* and some species of all other tested families have appeared naturally immune.

Geographical distribution: U. S., Canada, Bermuda, Japan, and Hungary. In California the celery-yellows strain of this virus replaces the type.

Induced disease: In most host species the characteristics of disease are clearing of veins, followed by chlorosis of newly formed tissues, stimulation of normally dormant buds to growth, malformation, virescence of flowers, sterility, and upright growth habit. Stimulation of nor

mally dormant buds to adventitious growth and abnormally erect habit are the most constant features. Chlorosis is absent or inconspicuous in some hosts.

Transmission: By leafhopper, *Macrosteles divisus* (Uhl.) (= *Cicadula sexnotata* (Fall.), *C. divisa* (Uhl.)) (*CICADELLIDAE*). Incubation period, about 2 weeks. Some strains of this virus are transmitted also by the leafhoppers *Thamnotettix montanus* Van D. and *T. geminatus* Van D. (*CICADELLIDAE*). By grafting. By dodder. Not through seeds of diseased plants. Not by mechanical inoculation of plants, but virus has been passed from insect to insect mechanically in *Macrosteles divisus;* juice from viruliferous insects contains little virus just after inoculation, but the effective concentration increases at least 100-fold between the 2nd and 12th day of a 17-day incubation period; it seems greatest before the insects begin to infect the aster plants on which they are maintained.

Thermal inactivation: In juice from viruliferous insects, at about 40° C in 10 minutes; at 25° C in 2 to 3 hours. In plant tissues, at 38° to 42° C, in 2 to 3 weeks; cured plants fully susceptible to reinfection. In insect vector, *M. divisus*, at 31° C in 12 days.

Other properties: Virus in juices derived from insects is more stable at 0° C than at 25° C or when frozen; at 0° C it withstands storage 24, not 48, hours in 0.85 per cent NaCl solution at pH 7.0 but most of the virus is inactivated in this time; it withstands dilution 1:1000 in neutral 0.85 per cent NaCl solution; for brief (less than 5-minute) exposures, it remains viable over the range from pH 5 to 9.

Literature: Black, Phytopath., *31*, 1941, 120–135; *33*, 1943, 2 (Abst.); Johnson, *ibid.*, *31*, 1941, 649–656; Kunkel, Am. Jour. Bot., *13*, 1926, 646–705; Contrib. Boyce Thompson Inst., *3*, 1931, 85–123; *4*, 1932, 405–414; Am. Jour. Bot., *24*, 1937, 316–327; *28*, 1941, 761–769; Linn, Cornell Agr. Exp. Sta. (Ithaca), Bull. 742, 1940; Ogilvie, Bermuda Dept. Agr., Agr. Bull. 6, 1927, 7–8; Severin, Hilgardia, *3*, 1929, 543–583; Phytopath., *20*, 1930, 920–921; Hilgardia, *7*, 1932, 163–179; *8*, 1934, 305–325, 339–361; Phytopath., *30*, 1940, 1049–1051; Hilgardia, *14*, 1942, 411–440; Severin and Haasis, Hilgardia, *8*, 1934, 329–335.

Strains: Two variant strains, one found in nature, the other derived experimentally, have been given varietal names to distinguish them from the type variety, *vulgaris* H. (*loc. cit.*, 2):

1a. *Chlorogenus callistephi* var. *californicus* H. (*loc. cit.*, 3). From California, name of state in which this strain was first recognized. Common name: Celery-yellows strain of aster-yellows virus. Differing from the type variety by ability to infect celery (*Apium graveolens* L.—*UMBELLIFERAE*) and zinnia (*Zinnia elegans* Jacq.—*COMPOSITAE*) (Kunkel, Contrib. Boyce Thompson Inst., *4*, 1932, 405–414; Severin, Hilgardia, *3*, 1929, 543–583; *8*, 1934, 305–325).

1b. *Chlorogenus callistephi* var. *attenuatus* H. (*loc. cit.*, 4). From Latin *attenuatus*, weakened. Common name: Heat-attenuated strain of aster-yellows virus. Differing from the type variety by inducing less severe chlorosis and less uprightness of new growth in affected aster plants (Kunkel, Am. Jour. Bot., *24*, 1937, 316–327).

2. **Chlorogenus australiensis** *comb. nov.* From Australia, name of continent. Synonym: *Galla australiensis* H. (*loc. cit.*, 107).

Common names: Tomato big-bud virus; virescence virus; perhaps also stowboor virus, tobacco stolbur or montar virus, eggplant little-leaf virus.

Hosts: *SOLANACEAE—Datura stramonium* L., Jimson weed; *Lycopersicon esculentum* Mill., tomato; *Nicotiana tabacum* L., tobacco; *Solanum melongena* L., eggplant; *S. nigrum* L., black nightshade. Recently a long list of species in this and

other families have been reported as susceptible to virescence virus, presumed to be an isolate of tomato big-bud virus. (Hill, Jour. Counc. Sci. Ind. Res., *16*, 1943, 85–92).

Geographical distribution: Australia, especially New South Wales; viruses causing somewhat similar diseases have been reported also from the Crimea and the northwestern United States.

Induced disease: In tomato, flowers erect, virescent, calyx bladder-like, pollen sterile; floral proliferation. Growth of axillary shoots stimulated. New leaves progressively smaller. Youngest leaves yellowish-green in color, especially at their margins; usually purplish underneath. Hypertrophy of inner phloem. No intracellular inclusions. Fruit reddens imperfectly and becomes tough and woody. Roots appear normal. In *Solanum nigrum*, axillary shoots numerous, leaves small, internal phloem adventitious. In tobacco, plants dwarfed; leaves recurved, distorted, twisted, thickened, brittle, yellowish green, hanging down close to stem; small leaves on shoots from axillary buds; proliferation and virescence of flowering parts; chlorotic clearing of veins as early effect of disease; upper surface of foliage appears glazed; some necrosis of veins, in old leaves, near tips and margins or on midrib; viable seed rarely produced; calyx bladder-like, floral axis may form short branches bearing small leaves; disease sometimes called bunchy top.

Transmission: By leafhopper, *Thamnotettix argentata* Evans (*CICADELLIDAE*). Experimentally by budding and other methods of grafting. Not by inoculation of expressed juice.

Literature: Cobb, Agr. Gaz. New South Wales, *13*, 1902, 410–414; Dana, Phytopath., *30*, 1940, 866–869; Hill, Jour. Austral. Inst. Agr. Sci., *6*, 1940, 199–200; Jour. Council Sci. Ind. Res., *10*, 1937, 309–312; *16*, 1943, 85–92; Michailowa, Phytopath., *25*, 1935, 539–558; Rischkov et al., Ztschr. Pflanzenkr., *43*, 1933, 496–498; Samuel et al., Phytopath., *23*, 1933, 641–653.

3. **Chlorogenus persicae** H. (*loc. cit.*, 5). From New Latin *Persica*, former generic name of peach.

Common names: Peach-yellows virus, little-peach virus.

Hosts: *ROSACEAE—Prunus persica* (L.) Batsch, peach; *P. salicina* Lindl., Japanese plum; and all other tested species of the genus *Prunus*.

Geographical distribution: Eastern United States and Canada, south to North Carolina. First occurred near Philadelphia in this country. Origin perhaps oriental; introduction in oriental plums suspected. Not in Europe.

Induced disease: In peach, clearing of veins, production of thin erect shoots bearing small chlorotic leaves, followed by death in a year or two. In early stages of the disease there is premature ripening of fruit. In Japanese plum, systemic infection but no obvious symptoms.

Transmission: By the leafhopper, *Macropsis trimaculata* (Fitch) (*CICADELLIDAE*). By budding; virus spreads down stem from point of bud insertion faster than up. Not by inoculation of expressed juice, despite numerous attempts. Not by pollen of diseased trees.

Immunological relationships: Presence of peach-yellows virus immunizes tree against little-peach virus, formerly considered an independent entity.

Thermal inactivation: In peach tissues, at 34° to 35° C in 4 to 5 days; at 44° C in 30 minutes; at 47° C in 10 minutes; at 50° C in 3 to 4 minutes; at 56° C in 15 seconds.

Other properties: Trees and bud sticks may be treated safely with heat sufficient to kill the virus. Cured trees are susceptible to reinfection.

Literature: Blake, N. J. Agr. Exp. Sta., Bull. 226, 1910; Kunkel, Contrib. Boyce Thompson Inst., *5*, 1933, 19–28; Phytopath., *26*, 1936, 201–219, 809–830; *28*, 1938, 491–497; Manns, Trans. Peninsula Hort. Soc., *23*, 1933, 17–19; Manns and Manns,

ibid., *24*, 1934, 72–76; McCubbin, Pennsylvania Dept. Agr., Gen. Bull. *382*, 1924.

Strains: Numerous strains of peach-yellows virus probably exist in nature. One of these has been given a varietal name, distinguishing it from the type variety, *vulgaris* H. (*loc. cit.*, 5):

3a. *Chlorogenus persicae* var. *micropersica* H. (*loc. cit.*, 6). From Greek *micros*, small, and New Latin *Persica*, former generic name of peach. Common name: Little-peach strain of peach-yellows virus. Differing from the type variety by tendency to cause a mild type of disease, characterized by distortion of young leaves, production of many short branches on main trunk, later yellowing of mature leaves, twiggy growth, shoots slightly less erect than in typical peach yellows. (Kunkel, Phytopath., *26*, 1936, 201–219; *26*, 1936, 809–830; *28*, 1938, 491–497; Manns, Trans. Peninsula Hort. Soc., *23*, 1933, 17–19; *24*, 1934, 72–76.)

4. **Chlorogenus solani** H. (*loc. cit.*, 7). From New Latin *Solanum*, generic designation of potato. Synonym: *Chlorophthora solani* McKinney, Jour. Washington Acad. Sci., *34*, 1944, 151.

Common names: Potato witches'-broom virus, potato wilding or semi-wilding virus.

Hosts: *SOLANACEAE—Solanum tuberosum* L., potato. Experimentally, also *SOLANACEAE—Lycopersicon esculentum* Mill., tomato; *Nicotiana tabacum* L., tobacco; *N. glutinosa* L.; *N. rustica* L. *APOCYNACEAE—Vinca rosea* L., periwinkle. *CHENOPODIACEAE—Beta vulgaris* L., sugar beet.

Geographical distribution: United States (Montana, Washington), Russia.

Induced disease: In potato, increasingly pronounced flavescence in new leaflets on one or more stems, production of new dwarfed leaflets with marginal flavescence on stems with unusually long internodes and enlarged nodes, growth of spindling axillary and basal branches. profuse blooming and fruiting, lack of dormancy in tuber buds, formation of many small underground tubers as well as some aerial tubers; plants grown from diseased tubers form thread-like stems and small simple leaves; infected plants survive several seasons, with progressive degeneration. In tomato, experimentally, extreme leaf dwarfing, marginal flavescence of leaves and abnormally numerous axillary branches; stems become hollow and die; plants do not survive long after infection. In tobacco, experimentally, slender axillary branches with dwarfed leaves, flowers on spindling pedicels, numerous, small; later leaves flavescent or marginally flavescent.

Transmission: By tuber-core grafts with prepatent period of 29 to 114 days. By stem grafts. By dodder, *Cuscuta campestris* Yuncker (*CONVOLVULACEAE*). Not by inoculation of expressed juice. Not by *Macrosteles divisus* (Uhl.) (*CICADELLIDAE*). No insect vector is known. Not through seeds of diseased tomatoes.

Thermal inactivation: at 42° C in 13 days, in tissues of *Vinca rosea*; at 36° C in 6 days in small potato tubers.

Literature: Hungerford and Dana, Phytopath., *14*, 1924, 372–383; Kunkel, in Virus Diseases, Cornell Univ. Press, Ithaca, N. Y., 1943, 63–82; Proc. Am. Philosoph. Soc., *86*, 1943, 470–475; McLarty, Scient. Agr., *6*, 1926, 395; Whipple, Montana Agr. Exp. Sta., Bull. 130, 1919; Young, Science, *66*, 1927, 304–306; Am. Jour. Bot., *16*, 1929, 277–279; Young and Morris, Jour. Agr. Res., *36*, 1928, 835–854.

5. **Chlorogenus santali** H. (*loc. cit.*, 8). From New Latin *Santalum*, generic designation of sandal.

Common names: Sandal spike-disease virus, sandal spike-rosette virus.

Hosts: *SANTALACEAE—Santalum album* L., sandal. Spike-like diseases have been found also in *RHAMNEAE—Zizyphus oenoplia* Mill., *SAPINDACEAE—Dodonaea viscosa* Jacq., *VER-*

BENACEAE—Stachytarpheta indica Vahl, and *APOCYNACEAE—Vinca rosea* L.

Geographical distribution: South India.

Induced disease: In sandal, abnormally profuse blooming at first, suppression of blooming later; reduction in leaf size and internode length; death ensues in the third year or earlier. In all but the youngest leaves of affected branches, vacuolate intracellular bodies with definite peripheral membrane, 4 to 9 microns in maximum diameter, are found.

Transmission: By twig grafts, inserted buds, and patch grafts, with success decreasing in the order named. Prepatent period 3 to 4 months. Best results in May and June; poorest in October. Perhaps through seeds, but not through pollen of diseased plants. Insect transmission claimed, but species not identified. Reported transmission by *Moonia albimaculata* (*CICADELLIDAE*) requires further confirmation. Not by inoculation of expressed juice. Not by root grafts.

Literature: Coleman, Mysore Dept. Agr., Mycol. Ser., Bull. 3, 1917; Indian Forester, *49*, 1923, 6–9; Dover, *ibid.*, *60*, 1934, 505–506; Narasimhan, Phytopath., *23*, 1933, 191–202; Rangaswami and Sreenvasaya, Current Science, *4*, 1935, 17–19; Sreenvasaya, Nature, *126*, 1930, 957; Venkata Rao and Gopala Iyengar, Mysore Sandal Spike Invest. Comm., Bull. 4, 1934, 1–12; Indian Forester, *60*, 1934, 689–701.

6. **Chlorogenus vaccinii** H. (*loc. cit.*, 10). From New Latin *Vaccinium*, generic designation of cranberry.

Common names: Cranberry false-blossom virus, Wisconsin false-blossom virus.

Hosts: *ERICACEAE—Vaccinium macrocarpon* Ait., cranberry; *V. oxycoccus* L. Experimentally, also *APOCYNACEAE—Vinca rosea* L., periwinkle. *COMPOSITAE—Calendula officinalis* L., calendula. *SOLANACEAE—Lycopersicon esculentum* Mill., tomato; *Nicotiana glutinosa* L.; *N. tabacum* L., tobacco; *Solanum tuberosum* L., potato.

Geographical distribution: Eastern United States and Canada. It is believed that the virus does not spread in bogs with alkaline (pH 7.4 to 8.8) flooding water in Wisconsin though it spreads rapidly in the more productive bogs with nearly neutral (pH 6.0 to 7.0) flooding water.

Induced disease: In cranberry, flowers erect, instead of pendent as in healthy plants; calyx lobes enlarged, petals short, streaked with red and green, stamens and pistils abnormal. Flowers may be replaced by leaves or short branches. Dormancy of axillary buds is broken, producing numerous erect shoots, forming a witches' broom. Diseased fruits small, irregular in shape, erect.

Transmission: By leafhopper, *Ophiola striatula* (Fall.) (=*Euscelis striatulus* (Fall.)) (*CICADELLIDAE*). Not by inoculation of expressed juice. By dodder, *Cuscuta campestris* Yuncker (*CONVOLVULACEAE*).

Thermal inactivation: At 40° C in 2 weeks in tissues of periwinkle.

Literature: Dobroscky, Contrib. Boyce Thompson Inst., *3*, 1931, 59–83; Fracker, Phytopath., *10*, 1920, 173–175; Kunkel, Science, *95*, 1942, 252; Torreya, *43*, 1943, 87–95; Shear, U. S. Dept. Agr., Bull. 444, 1916; Stevens, Phytopath., *15*, 1925, 85–91; *34*, 1944, 140–142; U. S. Dept. Agr., Circular 147, 1931; Stevens and Sawyer, Phytopath., *16*, 1926, 223–227; Wilcox and Beckwith, Jour. Agr. Res., *47*, 1933, 583–590.

7. **Chlorogenus robiniae** H. (*loc. cit.*, 13). From New Latin *Robinia*, generic designation of locust. Synonym: *Polycladus robiniae* McKinney, Jour. Washington Acad. Sci., *34*, 1944, 151.

Common names: Locust witches'-broom virus; locust brooming-disease virus.

Hosts: *LEGUMINOSAE—Robinia pseudoacacia* L., black locust.

Geographical distribution: United

States (southern Pennsylvania to northeastern Georgia, west to southwestern Ohio and Tennessee).

Induced disease: In black locust, clearing of veins, followed by progressive reduction in size of newly formed leaves; growth of spindly shoots to form witches' brooms. Roots more brittle, shorter, and darker than normal, with excessive branching of rootlets, giving the appearance of root brooms.

Transmission: By grafting and budding. Not by inoculation of expressed juice. No insect vector is known.

Literature: Grant et al., Jour. Forestry, *40*, 1942, 253–260; Hartley and Haasis, Phytopath., *19*, 1929, 163–166; Jackson and Hartley, Phytopath., *23*, 1933, 83–90; Waters, Plant World, *1*, 1898, 83–84.

8. **Chlorogenus medicaginis** H. (*loc. cit.*, 14). From New Latin *Medicago*, generic designation of alfalfa (lucerne).

Common names: Alfalfa witches'-broom virus, lucerne witches'-broom virus, spindle-shoot virus, mistletoe virus, Kurrajong virus, bunchy-top virus.

Hosts: *LEGUMINOSAE—Medicago sativa* L., alfalfa (lucerne).

Geographical distribution: Australia, especially New South Wales; perhaps United States.

Induced disease: In alfalfa, plant dwarfed; leaves small, rounded, chlorotic at edge, puckered, distorted; stems short, spindly, numerous. Flowers usually not formed, but sometimes pale and small, sometimes replaced by leafy structures. Seed rarely produced.

Transmission: By grafting. Not by inoculation of expressed juice. No insect vector is known.

Literature: Edwards, Jour. Australian Inst. Agr. Sci., *1*, 1935, 31–32; New South Wales Dept. Agr., Science Bull. 52, 1936; Agr. Gaz. New South Wales, *47*, 1936, 424–426; Richards, U. S. Dept. Agr., Plant Disease Reporter, Supplement, *71*, 1929, 309–310.

9. **Chlorogenus humuli** H. (*loc. cit.*, 15). From New Latin *Humulus*, generic designation of the hop.

Common names: Hop-nettlehead virus, silly-hill disease virus, virus of infectious-sterility of the hop.

Hosts: *MORACEAE—Humulus lupulus* L., European hop.

Geographical distribution: England, Czechoslovakia, Germany, Poland.

Induced disease: In hop, stems numerous, spindly, short, plants weak. Leaves curled upward at margin; cone production greatly reduced.

Transmission: By grafting. Not by inoculation of expressed juice. Not through soil. No insect vector is known.

Literature: Blattný and Vukolov, Rec. Inst. Rech. Agron. Rép. Tchécosl., *137*, 1935, 3–18; Goodwin and Salmon, Jour. Inst. Brew., *33*, 1936, 209–210; Salmon, *ibid.*, *32*, 1935, 235–237; *33*, 1936, 184–186; Salmon and Ware, Jour. South-Eastern Agr. College, Wye, Kent. *37*, 1936, 21–25.

Genus II. Carpophthora *McKinney emend.*

(Jour. Washington Acad. Sci., *34*, 1944, 152.)

Peach X-Disease Group; viruses inducing diseases characterized in general by rosetting of foliage and sometimes death of host. Generic name from Greek, meaning fruit and ruin or destruction.

The type species is *Carpophthora lacerans* McKinney.

Key to the species of genus Carpophthora.

I. Inducing chlorosis, reddening, and tattering of foliage, with rosette formation late in the disease in some hosts.

1. *Carpophthora lacerans*.

II. Inducing rosette formation characteristically, but not tattering of affected foliage.

2. *Carpophthora rosettae.*

1. **Carpophthora lacerans** (Holmes) McKinney. (*Marmor lacerans* Holmes, Handb. Phytopath. Viruses, 1939, 82; McKinney, Jour. Washington Acad. Sci., *34*, 1944, 152.) From Latin *lacerare*, to lacerate, in reference to characteristic foliage injury.

Common name: Peach X-disease virus; virus of peach yellow-red virosis.

Hosts: *ROSACEAE—Prunus persica* (L.) Batsch, peach; *P. virginiana* L., chokecherry.

Geographical distribution: United States, Canada.

Induced disease: In peach, foliage normal each spring but yellowish areas appear in June at base of leaves; affected trees appear lighter green than neighboring healthy trees; discolored spots occur at random on the leaf blade, becoming red and yellow with remainder of leaf becoming chlorotic; the discolored areas usually fall out, leaving the foliage tattered; subsequently, affected leaves drop except at tips of branches; young trees may die, older ones survive indefinitely. Fruit either shrivels and falls or ripens prematurely, with bitter flavor and no viable seed. In chokecherry, conspicuous premature reddening of foliage, development of fruits with dead embryos in the pits; in the second and third seasons after infection, duller colors of foliage, rosettes of small leaves on terminals; death follows the advanced stage of disease.

Transmission: By budding. Not by inoculation of expressed juice. No insect vector has been reported.

Literature: Berkeley, Div. of Botany and Plant Path., Science Service, Dominion Dept. Agr., Ottawa, Canada, Publication *678*, 1941; Boyd, U. S. Dept. Agr., Plant Dis. Rep., *22*, 1938, 334; Hildebrand, Contrib. Boyce Thompson Inst., *11*, 1941, 485–496; Hildebrand and Palmiter, U. S. Dept. Agr., Plant Dis. Rep., *22*, 1938, 394–396; Hildebrand et al., Handbook of virus diseases of stone fruits in North America, Michigan Agr. Exp. Sta., Misc. Publ., 1942, 21–24; Stoddard, Connecticut Agr. Exp. Sta., Circ. *122*, 1938, 54–60; Proc. Connecticut Pomol. Soc., *48*, 1938, 29–32.

2. **Carpophthora rosettae** (Holmes) *comb. nov.* (*Chlorogenus rosettae* H., *nomen nudum*, Phytopath. *29*, 1939, 434; *Nanus rosettae* H., Handb. Phytopath. Viruses, 1939, 125.) From rosette, common name of induced disease, from French, diminutive of *rose*, a rose.

Common name: Peach-rosette virus.

Hosts: *ROSACEAE—Prunus persica* (L.) Batsch, peach; *P. communis* Fritsch, almond; *P. domestica* L., plum. Experimentally, also—*APOCYNACEAE—Vinca rosea* L., periwinkle. *ROSACEAE—P. americana* Marsh., wild plum; *P. armeniaca* L., apricot; *P. cerasus* L., cherry; *P. pumila* L., sand cherry. *SOLANACEAE—Lycopersicon esculentum* Mill., tomato; *Nicotiana glutinosa* L.

Geographical distribution: United States (Georgia, Alabama, South Carolina, Tennessee, West Virginia, Missouri, Oklahoma).

Induced disease: In peach, sudden wilting and death, or growth of abnormally short stems bearing dwarfed leaves with clearing and thickening of veins, followed by death in a few months.

Transmission: By budding. By dodder, *Cuscuta campestris* Yuncker. Not by inoculation of expressed juice. Not through soil. No insect vector is known.

Immunological relationships: No protection is afforded by previous infection of peach trees with *Chlorogenus persicae*, peach-yellows virus.

Thermal inactivation: At 50° C in 10 minutes (in tissues of peach). Rosetted trees are abnormally susceptible to heat

injury and heat treatments cure peach-rosette disease only in recently infected trees.

Literature: Kunkel, Phytopath., *26*, 1936, 201–219, 809–830; in Virus Diseases, Cornell Univ. Press, Ithaca, N. Y., 1943, 63–82; McClintock, Jour. Agr. Res., *24*, 1923, 307–316; Phytopath., *21*, 1931, 373–386; Smith, U. S. Dept. Agr., Div. Veg. Path., Bull. 1, 1891.

Genus III. Morsus *gen. nov.*

Alfalfa-Dwarf Group; viruses inducing diseases characterized in general by sudden wilting and death or by gradual decline of vigor with foliage of darker green color than normal. Vectors, like those of the typical yellows subgroup, cicadellid leafhoppers so far as known. Generic name from Latin *morsus*, sting or vexation.

The type species is *Morsus suffodiens spec. nov.*

Key to the species of genus Morsus.

I. Affecting alfalfa and grape.
 1. *Morsus suffodiens.*

II. Affecting tobacco.
 2. *Morsus reprimens.*

III. Affecting elm.
 3. *Morsus ulmi.*

1. **Morsus suffodiens** *spec. nov.* From Latin *suffodere*, to sap or undermine, in reference to process leading to sudden collapse of long infected, but sometimes not obviously injured, grape vines as well as to progressive decline in size of infected alfalfa plants, the foliage of which may remain green to the last.

Common names: Alfalfa-dwarf virus, lucerne dwarf-disease virus, virus of Pierce's disease of the grape, virus of Anaheim disease.

Hosts: *LEGUMINOSAE—Medicago sativa* L., alfalfa (lucerne). *VITACEAE—Vitis vinifera* L., grape.

Geographical distribution: United States.

Induced disease: In alfalfa, leaves small but green, plant progressively smaller, wood of roots discolored yellow, transpiration decreased; wilting may occur; starch of root diminished; plant eventually succumbs, thinning stand prematurely. In grape, dark green color of leaves retained along veins, not between them, or no abnormality in appearance of foliage; wilting and sudden death of plant in summer of second year. In late summer of first year, there may be dying leaf margins and dying back of cane tips.

Transmission: By budding and root grafting. By leafhoppers, *Draeculacephala minerva* Ball, *Carneocephala fulgida* Nott., *C. triguttata* Nott., *Helochara delta* Oman, *Neokolla circellata* (Baker), *N. gothica* (Sign.), *N. confluens* (Uhler), *N. heiroglyphica* (Say), and *Cuerna occidentalis* Oman and Beamer (*CICADELLIDAE*); these vectors all belong to the subfamily *Amblycephalinae;* all tested species of this, but none of any other, subfamily have proved capable of transmitting this virus. Not by inoculation of expressed juice. Not through soil.

Literature: Frazier, Phytopath., *34*, 1944, 1000–1001; Hewitt, Phytopath., *29*, 1939, 10; *31*, 1941, 862; Blue Anchor, *18*, 1941, 16–21, 36; Hewitt et al., Phytopath., *32*, 1942, 8; Houston et al., Phytopath., *32*, 1942, 10; Milbrath, Calif. Dept. Agr., 20th Ann. Rept., Bull. *28*, 1940, 571; Pierce, U. S. Dept. of Agr., Div. of Veg. Path., Bull. *2*, 1892, 1–222; Weimer, Phytopath., *21*, 1931, 71–75; *27*, 1937, 697–702; Jour. Agr. Res., *47*, 1933, 351–368; *53*, 1936, 333–347; *55*, 1937, 87–104.

2. **Morsus reprimens** *spec. nov.* From Latin *reprimere*, to restrain, check, or curb, in reference to the inhibiting effect on growth of the host plant, tobacco.

Common name: Tobacco yellow-dwarf virus.

Hosts: *SOLANACEAE—Nicotiana tabacum* L., tobacco; *N. rustica* L., Indian tobacco; *N. trigonophylla* Dun. Experimentally, also *N. glauca* Grah. (symptomless) and *N. glutinosa* L.

Geographical distribution: Australia (Victoria, New South Wales, South Australia, and southern Queensland).

Induced disease: In tobacco, internodes of stem shortened, leaves small; downward bending of tips and rolling under of margins of young apical leaves; young leaves darker than normal at first, bunched, later appear ribbed; leaves become yellow-green, pale first between veins; old leaves rugose, thickened, later savoyed. Root system small, roots slightly brown externally and in the region of the phloem. Affected plants may survive the winter and show diseased new growth in the spring.

Transmission: By grafting and budding. By nymphs and adults of the leafhopper, *Thamnotettix argentata* (Evans) (*CICADELLIDAE*).

Literature: Dickson, Australia, Council Sci. Indust. Res., Pamphlet 14, 1929, 22; Hill, Australia, Journal of the Council Sci. Indust. Res., *10*, 1937, 228–230; *14*, 1941, 181–186; *15*, 1942, 13–25.

3. **Morsus ulmi** *spec. nov.* From Latin *ulmus*, elm.

Common name: Elm phloem-necrosis virus.

Host: *URTICACEAE—Ulmus americana* L., American elm.

Geographical distribution: United States (Ohio, Indiana, Illinois, Missouri, Tennessee, Kentucky, and West Virginia).

Induced disease: In elm, gradual decline over a period of 12 to 18 months before death or sudden wilt, drying of leaves, and death within 3 to 4 weeks. All ages susceptible, from seedling to large tree.

Transmission: By patch grafting. Not by inoculation of expressed juice.

Literature: Leach and Valleau, U. S. Dept. Agr., Plant Dis. Rept., *23*, 1939, 300–301; Swingle, Phytopath., *30*, 1940, 23.

Genus IV. **Aureogenus** *Black.*

(Proc. Am. Philos. Soc., *88*, 1944, 141.)

Viruses of the Yellow-Dwarf Group, inducing diseases characterized by yellowing without typical mosaic-type mottling. Vectors agallian leafhoppers (*CICADELLIDAE*). Generic name from Latin *aureus*, yellow or golden, and *genus*, group.

The type species is *Aureogenus vastans* (Holmes) Black.

Key to the species of genus **Aureogenus.**

I. Mechanically transmissible in some hosts by rubbing methods of inoculation. Not producing enlarged veins or club-leaf in clover.
  - 1. *Aureogenus vastans.*

II. Not known to be transmissible by rubbing methods of inoculation.
  - A. Producing enlarged veins in clover.
    - 2. *Aureogenus magnivena.*
  - B. Producing club-leaf in clover.
    - 3. *Aureogenus clavifolium.*

1. Aureogenus vastans (Holmes) Black. (*Marmor vastans* Holmes, Handb. Phytopath. Viruses, 1939, 94; Black, Proc. Am. Philos. Soc., *88*, 1944, 141.) From Latin *vastare*, to devastate.

Common name: Potato yellow-dwarf virus.

Hosts: *SOLANACEAE—Solanum tuberosum* L., potato. *COMPOSITAE—Chrysanthemum leucanthemum* L., var. *pinnatifidum* Lecoq and Lamotte, daisy; *Rudbeckia hirta* L., black-eyed Susan. *CRUCIFERAE—Barbarea vulgaris* R. Br., common winter cress. *LEGUMINOSAE—Trifolium pratense* L., red clover. Experimentally to numerous species in these and other families.

Geographical distribution: Northeastern United States and southeastern Canada.

Induced disease: In potato, yellowing of leaves, necrosis of stem, dwarfing of plant; the stem, if split, shows rusty specks especially at nodes and apex; the apex dies early; tubers are few, small, close to the stem, often cracked, with flesh discolored by scattered brown specks; seed tubers tend to remain unrotted in the ground, becoming hard and glassy; some of them do not germinate in warm soil, others produce shoots that die before reaching the surface, giving poor stands. In *Chrysanthemum leucanthemum* var. *pinnatifidum*, at first, clearing of veins; later, young leaves distorted, thick, stiff, small; petioles short, leaves erect, forming a rosette at the crown of the plant; with passing of the early phases of the disease, foliage tends to appear nearly normal, but remains darker green and more erect than that of healthy plants; virus is recoverable both during and after the period of obvious disease and infected plants may constitute an important reservoir. In *Trifolium incarnatum* L., crimson clover, experimentally, clearing of veins and yellowing of younger leaves (in summer the yellowing is usually replaced in part by an interveinal reddish-brown color on both leaf surfaces extending from the margins inwards); dwarfing of entire plant; death or a chronic disease characterized by milder manifestations without, however, vein enlargement or cupping of leaves. In *Nicotiana rustica* L., experimentally, yellowish primary lesions followed by clearing of veins and systemic chlorosis; the primary lesions facilitate quantitative estimation of concentrations of this virus.

Transmission: By inoculation of expressed juice, in the presence of finely powdered carborundum, to *Nicotiana rustica*; mechanical transmission very difficult in other hosts tested. By grafting. By clover leafhopper, *Aceratagallia sanguinolenta* (Provancher); experimentally, by other closely related leafhoppers, *Aceratagallia lyrata* (Baker), *A. obscura* Oman, and *A. curvata* Oman; not (for the type variety of the virus) by *Agallia constricta* Van Duzee; very rarely by *Agallia quadripunctata* (Provancher) and *Agalliopsis novella* (Say) (*CICADELLIDAE*). The vector *Aceratagallia sanguinolenta* remains infective as an overwintering adult; incubation period not less than 6 days, commonly much longer; virus does not pass to progeny of viruliferous leafhoppers through eggs or sperm; this leafhopper varies genetically in ability to transmit.

Immunological relationships: No protection is afforded against necrotic effects of a testing strain of this virus (var. *lethale* Black) by prior inoculation of *Nicotiana rustica* with isolates of *Marmor medicaginis*, *M. cucumeris*, *M. upsilon*, *Annulus tabaci*, *A. orae*, or *A. dubius*, but the varieties *vulgare* Black and *agalliae* Black protect; these specifically protecting strains give no similar protection against formation of necrotic lesions by subsequently applied isolates of *Marmor tabaci*, *M. lethale*, *Annulus tabaci*, or *A. orae*.

Thermal inactivation: At 50 to 52° C in 10 minutes.

Filterability: Passes Berkefeld W filter.

Other properties: Virus viable at 23 to 27° C less than 13 hours after extraction of juice from diseased plant; not infective after drying in leaf tissues.

Literature: Barrus and Chupp, Phytopath., *12*, 1922, 123–132; Black, Am. Potato Jour., *11*, 1934, 148–152; Cornell Univ. Agr. Exp. Sta., Mem. 209, 1937, 1–23; Phytopath., *28*, 1938, 863–874; Am. Jour. Bot., *27*, 1940, 386–392; Am. Potato Jour., *18*, 1941, 231–233; Phytopath., *33*, 1943, 363–371; Genetics, *28*, 1943, 200–209; Proc. Am. Philos. Soc., *88*, 1944, 132–144; Hansing, Cornell Univ. Agr. Exp. Sta., Bull. 792, 1943; Price and Black, Am. Jour. Bot., *28*, 1941, 594–595; Taylor, Am. Potato Jour., *15*, 1938, 37–40; Walker and Larson, Jour. Agr. Res., *59*, 1939, 259–280; Watkins, Jour. Econ. Ent., *32*, 1939, 561–564; Cornell Univ. Agr. Exp. Sta., Bull. 758, 1941, 1–24; Younkin, Am. Potato Jour., *19*, 1942, 6–11.

Strains: Beside the type variety, *Aureogenus vastans* var. *vulgare* Black (Am. Jour. Bot., *27*, 1940, 391), on which the species is based, two distinctive strains have been given varietal names:

1a. *Aureogenus vastans* var. *agalliae* Black. (Am. Potato Jour., *18*, 1941, 233.) From New Latin *Agallia*, generic name of vector of this strain. Common name: New Jersey strain of potato yellow-dwarf virus. Differing from the type especially in its distinctive vector, the leafhopper, *Agallia constricta* Van Duzee, which is incapable of transmitting the type strain, and in not being transmitted by *Aceratagallia sanguinolenta* (Provancher), common vector of the type variety. Experimentally, transmitted also by *Agallia quadripunctata* (Provancher); perhaps rarely by *Agalliopsis novella* (Say); Differing but little from the type in effects on potato (var. Green Mountain) and *Nicotiana rustica* but more definitely in effects on crimson clover, in affected plants of which a rusty-brown necrosis along the veins, not induced by the type strain, is always present in some degree.

1b. *Aureogenus vastans* var. *lethale* Black. (Am. Jour. Bot., *27*, 1940, 391.) From Latin *lethalis*, causing death. Common name: Strain B5 of potato yellow-dwarf virus. Differing from the type variety especially in a tendency to induce in *Nicotiana rustica*, experimentally, brown primary lesions with necrotic gray centers, systemic yellowing, extensive necrosis of veins, collapse of large areas of leaf, and sometimes death of the host; not known to occur in nature as a separate strain, but readily isolated as a variant from strains collected in nature.

2. **Aureogenus magnivena** Black. (Proc. Am. Philos. Soc., *88*, 1944, 144.) From Latin *magnus*, large, and *vena*, vein.

Common name: Clover big-vein virus.

Host: Experimentally, *LEGUMINOSAE—Trifolium incarnatum* L., crimson clover.

Insusceptible species: *SOLANACEAE—Nicotiana rustica* L., Indian tobacco; *Solanum tuberosum* L., potato.

Geographical distribution: United States (presumably, Washington, D. C.).

Induced disease: In crimson clover, experimentally, unevenly thickened veins which are depressed below the upper surface of the leaf; these enlarged veins, best observed from below, sometimes bear enations that arise from their lower surfaces, leaves often curl upward and inward marginally; in summer, yellowing of leaves progresses from margins inward, the yellow color being later replaced in part by red or purple red; petioles undulating; plants dwarfed; internodes shortened; no clearing of veins; no rusty-brown necrosis.

Transmission: Not by inoculation of expressed juice. By leafhoppers, *Agalliopsis novella* (Say), *Agallia constricta* Van Duzee, *A. quadripunctata* (Provancher); not by *Aceratagallia sanguinolenta* (Provancher) (*CICADELLIDAE*).

3. Aureogenus clavifolium Black. (Proc. Am. Philos. Soc., *88*, 1944, 141.) From Latin *clava*, club, and *folium*, leaf.

Common name: Clover club-leaf virus.

Host: Experimentally, *LEGUMINOSAE—Trifolium incarnatum* L., crimson clover.

Insusceptible species: *SOLANACEAE—Nicotiana rustica* L., Indian tobacco; *Solanum tuberosum* L., potato.

Geographical distribution: United States (Princeton, N. J.).

Induced disease: In crimson clover, experimentally, youngest leaves lighter green than normal, slow to unfold; leaf margins yellowed or colored red or purple red; affected leaves narrow, smooth or savoyed; plant dwarfed, new shoots from leaf axils slightly stimulated; new growth of spindly stems and small leaves; no rusty-brown necrosis of veins, no obvious enlargement of veins, and no obvious clearing of veins at the onset of disease.

Transmission: Not by inoculation of expressed juice. By leafhopper, *Agalliopsis novella* (Say) (*CICADELLIDAE*); not by leafhoppers, *Aceratagallia sanguinolenta* (Provancher), *Agallia constricta* Van Duzee, nor *A. quadripunctata* (Provancher) (*CICADELLIDAE*).

Genus V. Galla *Holmes.*

(*Loc. cit.*, 106)

Viruses of the Fiji-Disease Group, inducing diseases characterized by vascular proliferation. Generic name from Latin *galla*, a gall nut.

The type species is *Galla fijiensis* Holmes.

Key to the species of genus Galla.

I. Infecting sugar cane.
  A. Inducing formation of conspicuous galls.
    1. *Galla fijiensis.*
  B. Not inducing formation of conspicuous galls.
    2. *Galla queenslandiensis.*

II. Infecting anemone.
    3. *Galla anemones.*

III. Infecting peach.
    4. *Galla verrucae.*

IV. Infecting corn.
    5. *Galla zeae.*

1. Galla fijiensis Holmes. (Handb. Phytopath. Viruses, 1939, 106.) From name of Fiji Islands.

Common name: Fiji-disease virus.

Host: *GRAMINEAE—Saccharum officinarum* L., sugar cane.

Geographical distribution: Fiji Islands, New South Wales, Java, Philippine Islands, New Guinea and New Caledonia.

Induced disease: In sugar cane, galls on vascular bundles, formed by proliferation of phloem and nearby cells. Affected cells show characteristic spherical or oval inclusion bodies. Developing leaves shortened, crumpled, abnormally dark green. Infected stools of cane become bushy. Roots small, bunchy.

Transmission: By leafhoppers, *Perkinsiella saccharicida* Kirk. (in Queensland) and *P. vastatrix* Breddin (in Philippine Islands) (*FULGORIDAE*, subfamily *Delphacinae*). Not by grafting. Not by inoculation of expressed juice. Not through eggs of *P. vastatrix*. Cuttings taken from affected canes produce some healthy and some diseased plants, because virus does not become uniformly distributed throughout the host tissues.

Literature: Kunkel, Bull. Exp. Sta., Hawaiian Sugar Planters' Assoc., Bot.

Ser., *3*, 1924, 99–107; Lyon, *ibid.*, *3*, 1921, 1–43; Hawaiian Planters' Rec., *12*, 1915, 200; Mungomery and Bell, Queensland, Bur. Sugar Exp. Sta., Div. Path., Bull. 4, 1933; Ocfemia, Am. Jour. Bot., *21*, 1934, 113–120; Ocfemia and Celino, Phytopath., *29*, 1939, 512–517; Reinking, Phytopath., *11*, 1921, 334–337.

2. **Galla queenslandiensis** H. (*loc. cit.*, 109). From Queensland, where the induced disease was first studied.

Common name: Sugar-cane dwarf-disease virus.

Host: *GRAMINEAE—Saccharum officinarum* L., sugar cane.

Geographical distribution: Queensland.

Induced disease: In sugar cane, young leaves marked with scattered chlorotic streaks, leaves stiff and erect, spindle twisted, abnormally short and pale. As leaves mature, streaks disappear, leaves become darker than normal green. In recently infected plants, vascular bundles are enlarged, irregular in shape, fused and characterized by abnormal proliferation of thin-walled lignified cells.

Literature: Bell, Queensland, Bur. Sugar Exp. Sta., Div. Path., Bull. 3, 1932.

3. **Galla anemones** H. (*loc. cit.*, 108). From Latin *anemone*, anemone or windflower.

Common name: Anemone-alloiophylly virus.

Hosts: *RANUNCULACEAE—Anemone nemorosa* L., vernal windflower; *A. ranunculoides* L.; *A. trifolia* L.

Geographical distribution: Germany.

Induced disease: Leaves thickened and distorted, petioles thickened. Flowers distorted or not formed. Vascular bundles larger and more numerous than in healthy plants. Palisade cells short, chloroplasts smaller and fewer than normal.

Transmission: By needle puncture into rhizomes immersed in filtered juice of diseased plant. By contamination of soil with fragments of diseased leaves or rhizomes.

Literature: Klebahn, Bericht. d. Deutsch. Bot. Gesellsch., *15*, 1897, 527–536; Ztschr. wissensch. Biol., Abt. E, Planta, *1*, 1926, 419–440; *6*, 1928, 40–95; Phytopath. Ztschr., *4*, 1932, 1–36; *9*, 1936, 357–370.

4. **Galla verrucae** Blodgett. (Phytopath., *33*, 1943, 30.) From Latin *verruca*, wart. Originally spelled *verruca*, apparently by a typographical error, which was corrected twice on the following page, once in a statement that the genitive *verrucae* had been given as specific epithet.

Common name: Peach-wart virus.

Host: *ROSACEAE—Prunus persica* (L.) Batsch, peach.

Geographical distribution: United States (Idaho, Washington, Oregon).

Induced disease: In peach, no characteristic effect on foliage. Fruits blistered, welted, later with warty outgrowths conspicuously raised. Affected tissues light tan to red, rough, cracked and russeted, or smooth. Gumming usual, often severe. Warty tissue superficial; underlying tissues coarse, filled with gum pockets, but not abnormal in flavor. Warty tissue may be hard and bony, but more often it is merely tougher than normal.

Transmission: By budding and inarching.

Literature: Blodgett, Phytopath., *31*, 1941, 859–860 (Abst.); *33*, 1943, 21–32.

5. **Galla zeae** McKinney. (Jour. Washington Acad. Sci., *34*, 1944, 328.) From Latin *zea*, a kind of grain.

Common name: Wallaby-ear disease virus.

Host: *GRAMINEAE—Zea mays* L., corn (maize).

Geographical distribution: Southeastern Queensland, Australia.

Induced disease: In corn (maize), small swellings on secondary veins on undersides of young leaves, spreading to base and tip of leaf along veins; plant dwarfed, becoming abnormally deep green and deficient in development of pollen; silk, cobs, and grain retarded in growth.

Transmission: By leafhopper, *Cicadula bimaculata* Evans (*CICADELLIDAE*).

Literature: Schindler, Jour. Austral. Inst. Agr. Sci., *8*, 1942, 35–37.

Genus VI. Fractilinea *McKinney.*

(Jour. Washington Acad. Sci., *34*, 1944, 148.)

Viruses of the Stripe-Disease Group; hosts grasses; insect vectors, cicadellid and fulgorid leafhoppers. Generic name from Latin, meaning interrupted and line.

The type species is *Fractilinea maidis* (Holmes) McKinney.

Key to the species of genus Fractilinea.

I. Vectors, cicadellid leafhoppers.
   1. *Fractilinea maidis.*
   2. *Fractilinea oryzae.*
   3. *Fractilinea tritici.*
   4. *Fractilinea quarta.*

II. Vectors, fulgorid leafhoppers.
   5. *Fractilinea zeae.*
   6. *Fractilinea avenae.*

1. Fractilinea maidis (Holmes) McKinney. (*Marmor maidis* Holmes, Handb. Phytopath. Viruses, 1939, 56; *Fractilinea maidis* McKinney, Jour. Washington Acad. Sci., *34*, 1944, 149.) From New Latin *mays*, corn (i.e. maize).

Common name: Maize-streak virus.

Hosts: *GRAMINEAE—Zea mays* L., corn (maize); *Digitaria horizontalis* Willd., *Eleusine indica* Gaert.; *Saccharum officinarum* L., sugar cane.

Geographical distribution: Africa.

Induced disease: In corn, pale spots at base of young leaf, followed by chlorotic spotting and streaking of subsequently formed leaves. Virus moves rapidly (up to 40 cm in 2 hours at 30° C) after introduction into host plant by insect. More virus in chlorotic spots than in green areas of affected leaves.

Transmission: By leafhoppers, *Cicadulina* (= *Balclutha*) *mbila* (Naude), *C. zeae* China, and *C. storeyi* China (*CICADELLIDAE*). In *C. mbila* ability to transmit this virus is controlled by a sex-linked dominant gene; active male (AX) (Y), inactive male (aX) (Y), inactive female (aX) (aX), active female (AX) (AX) or (AX) (aX). Inactive individuals ingest virus when feeding, but can become infective only if the intestine is wounded purposely or accidentally. If inoculated artificially by introducing virus into blood, both active and inactive insects become infective. Incubation period, 6 to 12 hours at 30° C. Young not infected through the egg. Infective leafhopper cannot transmit virus unless feeding puncture exceeds a minimum period, about 5 minutes in duration. This virus has not been transmitted to its plant hosts by inoculation of expressed juices.

Filterability: At pH 6, passes Chamberland L_1 and L_3, Berkefeld V and N, filters; retained by Seitz E K filter disc.

Literature: Storey, Ann. Appl. Biol., *12*, 1925, 422–439; *15*, 1928, 1–25; *19*, 1932, 1–5; Proc. Roy. Soc., B, *112*, 1932, 46–60; *113*, 1933, 463–485; *125*, 1938, 455–477; Ann. Appl. Biol., *21*, 1934, 588–589; *24*, 1937, 87–94; East Afr. Agr. Jour., *1*, 1936, 471–475; Storey and McClean, Ann. Appl. Biol., *17*, 1930, 691–719.

Strains: Two strains that differ radically from the type, var. *typicum* H. (*loc. cit.*, 56), have been given varietal names, as follows:

1a. *Fractilinea maidis* var. *sacchari* H. (*loc. cit.*, 57). From New Latin *Saccharum*, generic name of sugar cane. Common name: Cane-streak strain of

maize-streak virus. Differing from the type strain in being specialized for attacking sugar cane, in which the type (from maize) tends to be localized or finally lost with resultant spontaneous recovery of the temporary host. The cane-streak strain usually spreads readily in the cane plant; leaves become much marked with broken, narrow, pale, longitudinal stripes and spots; stems remain unaffected. One variety of sugar cane, P.O.J. 213, is resistant and, if infected, tends to recover. (McClean, Intern. Soc. Sugar Cane Techn., Bull. 27, 1932; Proc. So. Afr. Sugar Techn. Assoc., 1936, 1–11; Storey, Rept. Imp. Bot. Conf., London, 1924, 132–144; Union So. Afr. Dept. Agr., Sci. Bull. 39, 1935; Ann. Appl. Biol., *17*, 1930, 691–719.

1b. *Fractilinea maidis* var. *mitis* H. (*loc. cit.*, 58). From Latin *mitis*, mild. Common name: Mottle strain of maize-streak virus. Differing from the typical strain by the mildness of the disease induced in corn (maize), transitory chlorotic mottling of newly developed leaves, followed by fading of mottling and production of apparently normal leaves. Young leaves, while mottled, are less rigid than normal and may not remain as nearly erect as healthy leaves. (Storey, Ann. Appl. Biol., *24*, 1937, 87–94.)

2. **Fractilinea oryzae** (Holmes) *comb. nov.* (*Marmor oryzae* Holmes, *loc. cit.*, 64.) From Latin *oryza*, rice.

Common name: Rice dwarf-disease virus.

Hosts: *GRAMINEAE—Oryza sativa* L., rice. Experimentally, also *Alopecurus fulvus* L.; *Avena sativa* L., oat; *Echinochloa crusgalli* Beauv. var. *edulis* Honda; *Panicum miliaceum* L.; *Poa pratensis* L.; *Secale cereale* L., rye; *Triticum vulgare* Vill., wheat.

Insusceptible species: *GRAMINEAE —Zea mays* L., corn (maize); *Hordeum vulgare* L., barley; *Setaria italica* Beauv., foxtail millet; *Andropogon sorghum* Brot. (= *Holcus sorghum* L.), sorghum.

Geographical distribution: Japan, Philippine Islands.

Induced disease: In rice, yellowish green spots along veins of young leaf, followed by chlorotic spotting and streaking of subsequently formed leaves. Growth stunted, internodes and roots abnormally short, forming a dwarf plant. Vacuolate intracellular bodies, 3 to 10 by 2.5 to 8.5 microns in size, close to nuclei of cells in affected tissues.

Transmission: By leafhoppers, *Nephotettix apicalis* var. *cincticeps* Uhler, *N. bipunctatus* Fabr., and *Deltocephalus dorsalis* Motsch. (*CICADELLIDAE*). Virus transmitted through some of the eggs but through none of the sperm of infected individuals of *N. apicalis*. Transfer from individuals thus infected through the egg to their progeny likewise demonstrated, even to the 7th generation. This is the only confirmed instance of transmission of a phytopathogenic virus through the eggs of an insect vector and is considered as evidence that the virus multiplies within the body of its vector as well as in its plant hosts. Incubation period in insect usually 30 to 45 days after first feeding on an infected plant, sometimes as short as 10 or as long as 73 days; nymphs from viruliferous eggs do not become infective until 7 to 38 (average 19) days after emergence. Transmission by inoculation of expressed juice has not been demonstrated. No transmission through seeds from diseased rice plants. No soil transmission.

Literature: Agati et al., Philippine Jour. Agr., *12*, 1941, 197–210; Fukushi, Trans. Sapporo Nat. Hist. Soc., *12*, 1931, 35–41; Proc. Imp. Acad., Tokyo, *9*, 1933, 457–460; Jour. Fac. Agr. Hokkaido Imp. Univ., *37*, 1934, 41–164; Trans. Sapporo Nat. Hist. Soc., *13*, 1934, 162–166; Proc. Imp. Acad., Tokyo, *11*, 1935, 301–303; *13*, 1937, 328–331; *15*, 1939, 142–145; Jour. Fac. Agr. Hokkaido Imp. Univ., *45*, 1940, 83–154; Katsura, Phytopath.,

26, 1936, 887–895; Takata, Jour. Japan Agr. Soc., *171*, 1895, 1–4; *172*, 1896, 13–32 (Takata's papers, in Japanese, constitute the first published record of transmission by an insect of a virus causing disease in a plant, the leafhopper *Deltocephalus dorsalis* Motsch. transmitting dwarf-disease virus to rice; see Fukushi, 1937, cited above).

3. **Fractilinea tritici** McKinney. (Jour. Washington Acad Sci., *34*, 1944, 327.) From Latin *triticum*, wheat.

Common name: Winter-wheat mosaic virus.

Hosts: *GRAMINEAE—Triticum aestivum* L., wheat; *Secale cereale* L., rye; *Avena byzantina*; *A. fatua* L., wild oat; *A. sativa* L., oat; *Hordeum vulgare* L., barley.

Geographical distribution: Union of Soviet Socialist Republics.

Induced disease: In winter wheat and rye, chlorotic mottling; profuse branching. In winter wheat, phloem necrosis; chloroplasts few, small; vacuolate inclusions in cells; nuclei enlarged and with extra nucleoli; no protein crystals of the pupation-disease type in affected cells. In spring wheat, barley, and oats, chlorotic mottling without profuse branching; no proliferation of flowers, but grain is rarely formed, most infected plants dying before this stage of growth.

Transmission: By leafhopper, *Deltocephalus striatus* L. (*CICADELLIDAE*), with incubation period of 15 to 18 days. Not by inoculation of expressed juice. Not through soil.

Literature: Zazhurilo and Sitnikova, Compt. rend. Acad. Sci. U. R. S. S., *25*, 1939, 798–801; *26*, 1940, 474–478; *29*, 1940, 429–432; Proc. Lenin Acad. Agr. Sci., U. R. S. S., *6*, 1941, 27–29. [Rev. Appl. Myc., *19*, 1940, 268; *20*, 1941, 157, 396; *22*, 1943, 59].

4. **Fractilinea quarta** (Holmes) *comb. nov.* (*Marmor quartum* Holmes, *loc. cit.*, 65.) From Latin *quartus*, fourth.

Common name: Sugar-cane chlorotic-streak virus or fourth-disease virus.

Host: *GRAMINEAE—Saccharum officinarum* L., sugar cane.

Geographical distribution: Java, Queensland, Hawaii, Puerto Rico, Colombia, United States (Louisiana).

Induced disease: In sugar cane, reduction of growth rate; wilting at midday; long, narrow, longitudinal streaks, of creamy or white color, in the leaves. Streaks 1/16 to 3/16 inches wide, generally less than 1 foot long, fragmenting.

Transmission: By leafhopper, *Draeculacephala portola* Ball (*CICADELLIDAE*). Not demonstrated by inoculation of expressed juice.

Thermal inactivation: In cuttings, at 52° C in less than 20 minutes.

Literature: Abbott, Phytopath., *28*, 1938, 855–857; Sugar Bull., *16*, 1938, 3–4; Abbott and Ingram, Phytopath., *32*, 1942, 99–100; Bell, Queensland Agr. Jour., *40*, 1933, 460–464; Martin, Hawaiian Planters' Rec., *34*, 1930, 375–378; Hawaiian Sugar Planters' Assoc. Proc., *53*, 1934, 24–35.

5. **Fractilinea zeae** (Holmes) *comb. nov.* (*Marmor zeae* Holmes, *loc. cit.*, 59.) From New Latin *Zea*, generic name for corn (maize), from Latin *zea*, a kind of grain.

Common name: Maize-stripe virus.

Host: *GRAMINEAE—Zea mays* L., corn (maize).

Insusceptible species: *GRAMINEAE —Saccharum officinarum* L., sugar cane.

Geographical distribution: Hawaii, Tanganyika, Mauritius, Trinidad, Cuba. Not in United States.

Induced disease: In corn (maize), at first few, elongated, chlorotic lesions near base of young leaf, later enlarging and fusing to form continuous stripes. Subsequently formed leaves banded and striped variously. Vacuolate intracellular inclusions in cells of affected areas.

Transmission: By leafhopper, *Peregrinus maidis* (Ashm.) (*FULGORIDAE*); the incubation period in this in-

sect is usually between 11 and 29 days, although shorter periods have been demonstrated in a few cases. Virus may persist in the insect host until death, but may become exhausted earlier. Not by aphid, *Aphis maidis* Fitch (*APHIDIDAE*). Not by inoculation of expressed juice.

Literature: Briton-Jones, Trop. Agr., *10*, 1933, 119–122; Carter, Ann. Ent. Soc. Am., *34*, 1941, 551–556; Kunkel, Bull. Hawaiian Sugar Planters' Assoc., Bot. Ser., *3*, 1921, 44–57; 1924, 108–114; Hawaiian Planters' Rec., *26*, 1922, 58-64; Phytopath., *17*, 1927, 41 (Abst.); Stahl, Trop. Pl. Res. Found., Bull. 7, 1927; Storey, Rept. of Plant Pathologist, Amani Agr. Res. Station, 4th Ann. Rept., 1931-32, pp. 8–13.

6. **Fractilinea avenae** McKinney. (Jour. Washington Acad. Sci., *34*, 1944, 327.) From Latin *avena*, oats.

Common name: Pupation-disease virus.

Hosts: *GRAMINEAE*—*Avena sativa* L., oat; *Triticum aestivum* L., wheat; *Echinochloa crusgalli* Beauv.; *Setaria viridis*; rarely, *Agropyron repens* (L.) Beauv. and *Bromus inermis* Leyss. Experimentally, also *Hordeum vulgare* L., barley; *Panicum miliaceum* L., millet; *Oryza sativa* L., rice; *Secale cereale* L., rye; *Zea mays* L., corn (maize).

Geographical distribution: West Siberia.

Induced disease: In oat, chlorotic mottling, profuse development of shoots, proliferation of flowers with change to leaf-like structures. Protein crystals in affected cells have been regarded as accumulated virus.

Transmission: By leafhopper, *Delphax striatella* Fallan (*FULGORIDAE*), especially first and second instar nymphs; fifth instar nearly immune to infection. Incubation period, 6 days or more. Virus overwinters in insect as well as in plants. Not transmitted from an infected leafhopper to its progeny. Not through soil. Not through seeds from infected plants.

Literature: Sukhov et al., Compt. rend. Acad. Sci., U. R. S. S., *20*, 1938, 745–748; *26*, 1940, 479–482, 483–486.

FAMILY II. MARMORACEAE HOLMES EMEND.

(Handb. Phytopath. Viruses, 1939, 16.)

Viruses of the Mosaic Group, inducing diseases usually characterized by persistent chlorotic or necrotic spotting, and often by mottling. The family is here extended to include several small groups of viruses, formerly assigned independent family rank, but sharing a tendency to aphid transmission, so far as known, and inducing diseases characterized by abnormal growth habit, thickening and rolling of leaves, or dwarfing, traits not incompatible with the characters of the present group. Should any one of these small groups become the center of a large assemblage of new viruses in the future, separate familial status for it might again be advantageous. In the combined grouping here used, specific vectors, so far as known, are aphids (*APHIDIDAE*).

Key to the genera of family **Marmoraceae.**

I. Viruses of the Typical Mosaic-Disease Group.
 Genus I. *Marmor*, p. 1163.
II. Viruses of the Spindle-Tuber Group.
 Genus II. *Acrogenus*, p. 1202.
III. Viruses of the Leaf-Roll Group.
 Genus III. *Corium*, p. 1203.
IV. Viruses of the Dwarf-Disease Group.
 Genus IV. *Nanus*, p. 1206.
V. Viruses of the Rough-Bark Group.
 Genus V. *Rimocortius*, p. 1208.
VI. Viruses of the Symptomless Group.
 Genus VI. *Adelonosus*, p. 1211.

Genus I. **Marmor** *Holmes.*

(*Loc. cit.*, 16)

Viruses inducing typical mosaic diseases in various plants. Generic name from Latin *marmor*, a mottled substance.

The type species is *Marmor tabaci* Holmes.

Key to the groups within genus **Marmor.**

A. Relatively resistant to heat inactivation, usually requiring more than 10 minutes at 85 to 90° C for complete inactivation.
 1. Tobacco-Mosaic Virus Group.
B. Relatively susceptible to heat inactivation, requiring less than 10 minutes at 85 to 90° C for complete inactivation.
 a. Replacing potato-veinbanding virus in mixed infections.
  2. Tobacco-Etch Virus Group.
 aa. Not replacing potato-veinbanding virus in mixed infections.
  3. Cucumber-Mosaic Virus Group.
C. Many additional species cannot yet be grouped into definite subdivisions of the genus; they constitute a residual or
 4. Miscellaneous Mosaic-Virus Group.

Key to the species of the Tobacco-Mosaic Virus Group.

Viruses relatively resistant to heat inactivation, requiring in most cases more than 10 minutes at 85 to 90° C for complete inactivation. Insect vectors as yet unknown under natural conditions.

I. Found in nature principally in solanaceous plants; *Cucurbitaceae* insusceptible. Chlorotic mottling in some hosts, necrotic lesions in others as result of experimental infection. Suspensions show anisotropy of flow.
1. *Marmor tabaci.*
2. *Marmor constans.*

II. Found in nature only in cucurbitaceous plants; *Solanaceae* insusceptible. Only mottling as result of experimental infection. Suspensions show marked anisotropy of flow.
3. *Marmor astrictum.*

III. Found only in leguminous plants. Chlorotic lesions in some varieties of the common snap-bean plant, necrotic lesions in others, as a result of experimental infection.
4. *Marmor laesiofaciens.*

IV. Found in greenhouses confined to roots and lower parts of plants. Only necrotic lesions as result of experimental infection. Suspensions do not show anisotropy of flow.
5. *Marmor lethale.*

V. Found in tomato and experimentally transmissible to a number of species of plants in this and other families. Resembling the preceding in a number of physical characteristics, including failure to show anisotropy of flow.
5a. *Marmor dodecahedron.*

1. **Marmor tabaci** Holmes. (Holmes, Handb. Phytopath. Viruses, 1939, 17; *Musivum tabaci* Valleau, Phytopath., *30*, 1940, 822; *Phytovirus nicomosaicum* Thornberry, Phytopath., *31*, 1941, 23.) From New Latin *Tabacum*, early generic name for tobacco.

Common names: Tobacco-mosaic virus, tomato-mosaic virus.

Hosts: *SOLANACEAE—Nicotiana tabacum* L., tobacco; *Lycopersicon esculentum* Mill., tomato; and *Capsicum frutescens* L., garden pepper, among crop plants; nearly all, if not all, solanaceous plants can be infected, although in some the virus remains localized at or near the site of inoculation. *PLANTAGINACEAE*—A strain of this virus has been found in nature infecting *Plantago lanceolata* L., ribgrass, *P. major* L. and *P. rugelii* Dcne., common broad-leaved plantains. Experimental hosts are widely distributed through many related families of plants.

Geographical distribution: World-wide.

Induced disease: In most varieties of tobacco, yellowish-green primary lesions, followed by clearing of veins, distortion and greenish-yellow mottling of newly formed leaves. In Ambalema tobacco, no symptoms, virus being restricted to inoculated leaves or those nearby. Strains of tobacco showing necrotic effects have been produced recently. In tomato, no obvious primary lesions, systemic disease characterized by greenish-yellow mottling of foliage, moderate distortion of leaf shape, and a reduction of fruit yield not exceeding 50 per cent. If some strain of potato-mottle virus (*Marmor dubium*) is also present, a more severe disease is induced; this is known as double-virus streak, and is characterized by systemic necrosis. In most varieties of garden pepper, yellowish primary lesions followed by systemic chlorotic mottling. In the Tabasco pepper and its recent derivatives, recovery by abscission of inoculated leaf, after localization of virus in necrotic primary lesions. Vacuolate intracellular inclusions are found in chlorotic tissues of all hosts that show distinct chlorotic mottling.

Transmission: By slight abrasive contacts. By inoculation of expressed juice. To some extent by the aphids, *Myzus pseudosolani* Theob., *M. circumflexus* (Buckt.), *Macrosiphum solanifolii* Ashm., and *Myzus persicae* (Sulz.) (*APHIDIDAE*). By grafting. Through soil.

Through dodder, *Cuscuta campestris* Yuncker (*CONVOLVULACEAE*), without infecting this plant vector. Not through pollen from diseased plants. Not through seeds from diseased tobacco; seed transmission has been reported in the case of recently ripened seeds from diseased tomato.

Serological relationships: Precipitin test gives cross reactions between all known strains, except those characterized by failure to spread systemically in tobacco. No cross reactions with other viruses except weakly with cucurbit-mosaic virus (*Marmor astrictum*). Type and other strains of tobacco-mosaic virus give cross reactions in complement-fixation and neutralization tests.

Immunological relationships: Plant protection tests, particularly in *Nicotiana sylvestris* Spegaz. and Comes, have demonstrated that tissues invaded by any strain of this virus are immune to subsequent infection by the tomato aucuba-mosaic strain of tobacco-mosaic virus, indicating a group relationship not shared by other viruses, such as cucumber-mosaic virus or tobacco-ringspot virus.

Thermal inactivation: At 88 to 93° C in 10 minutes; at 86 to 92° C in 30 minutes.

Filterability: Tobacco-mosaic virus was the first virus shown to be filterable, by Iwanowski in 1892; its filterability was confirmed and interpreted by Beijerinck in 1898.

Other properties: The ultimate particles of tobacco-mosaic virus have been shown to be rod-shaped and isotropic, sometimes associated in pairs, end to end. Under proper conditions, thread-like paracrystals are formed. Specific gravity has been determined as about 1.37, refractive index as about 1.6. Isoelectric point between pH 3.2 and 3.5. Suspensions in media of lower refractive indices show anisotropy of flow. Sedimentation constants, at 20° C, 187×10^{-13} cm per sec. per dyne at infinite dilution for unaggregated virus and 216×10^{-13} cm per sec. per dyne for associated particles. The computed average length of the virus unit is about 272 millimicrons; diameter, 13.8 millimicrons. Electron micrographs show that characteristic particles are rod-like, between 10 and 20 millimicrons in width, variable in length, but in some preparations averaging 270 millimicrons in length for single units, 405 to 540 millimicrons in length for associated pairs; X-ray measurements in air-dry gel show width 15.20 ± 0.05 millimicrons. Solutions stronger than about 1.3 per cent separate into layers, the lower spontaneously doubly refracting and more concentrated than the upper. At concentrations of electrolytes somewhat less than are required to precipitate the virus as fibres or needle-shaped paracrystals, the solutions form clear gels that become fluid on shaking or diluting (at pH 7 and 30° C). The virus is destroyed by high-frequency sound radiation, by pressures between 6000 and 8000 kilograms per square centimeter, and by hydrogen-ion concentrations above pH 11 or below pH 1. It is relatively stable between pH 2 and pH 8. It is rapidly broken down in 6 M urea solutions, in the presence of salts, to low-molecular-weight components devoid of activity. Analysis of purified virus: carbon 47.7 per cent, hydrogen 7.35 per cent, nitrogen 15.9 per cent, sulfur 0.24 per cent, phosphorus 0.60 per cent, lipoid 0.0 per cent, carbohydrate 1.6 to 2.0 per cent. A revised estimate of the sulfur content is 0.20 per cent, probably all in cysteine; no methionine has been detected in the typical variety of this virus. The percentages of the following substances in the virus are: tyrosine 3.9, tryptophane 4.5, proline 4.6, arginine 9.0, phenylalanine 6.0, serine 6.4, threonine 5.3, cysteine 0.68, alanine 2.4, aspartic acid 2.6, glutamic acid 5.3, leucine 6.1, valine 3.9, nucleic acid 5.8, and amide nitrogen 1.9, collectively accounting for about 68 per cent of the total weight. Virus formation ceases in infected host tissues immersed in 0.0002 molar sodium cyanide solution, beginning again after removal of cyanide.

Literature: The literature dealing with tobacco-mosaic virus is too voluminous to permit citation of more than a few representative publications. Allard, U. S. Dept. Agr., Bull. 40, 1914; Bawden and Pirie, Proc. Roy. Soc. London, Ser. B., *123*, 1937, 274–320; Beale, Jour. Exp. Med., *54*, 1931, 463–473; Beijerinck, Verhandel. Konink. Akad. Wetenschappen te Amsterdam, II, *6*, 1898, 3–22; Grant, Phytopath., *24*, 1934, 311–336; Hoggan, Jour. Agr. Res., *49*, 1934, 1135–1142; Iwanowski, Bull. Acad. Imp. Sci. St. Petersburg, Ser. 4, *3*, 1892, 67–70; Jensen, Phytopath., 23, 1933, 964–974; Johnson, Science, 64, 1926, 210; Kausche et al., Naturwiss., *27*, 1939, 292–299; Knight, Jour. Biol. Chem., *147*, 1943, 663–666; Kunkel, Phytopath., *24*, 1934, 437–466; Lauffer, Jour. Am. Chem. Soc., *66*, 1944, 1188–1194; Price, Phytopath., *23*, 1933, 749–769; Stanley, Phytopath., *26*, 1936, 305–320; Takahashi and Rawlins, Proc. Soc. Exp. Biol. and Med., *30*, 1932, 155–157; Valleau and Johnson, Kentucky Agr. Exp. Sta., Bull. 376, 1937; Vinson, Science, *66*, 1927, 357–358; Woods, Science, *91*, 1940, 295–296.

Strains: A great number of variant strains have been isolated both experimentally and from plants infected in nature. These usually share with the type variety most of the fundamental properties, particle size, especially width, stability at relatively high temperatures, longevity in storage, some common antigens. The following have been distinguished from the type, var. *vulgare* H. (*loc. cit.*, 17), by varietal names:

1a. *Marmor tabaci* var. *aucuba* H. (*loc. cit.*, 20). A group of isolates producing necrotic local lesions in inoculated leaves of *Nicotiana sylvestris* Spegaz. and Comes; useful in identifying many other strains of this virus which on prior application protect the tissues of this plant from the necrotic effects of aucuba-type strains (Smith, Ann. Appl. Biol., *18*, 1931, 471–493; Kunkel, Phytopath., *24*, 1934, 437–466).

1b. *Marmor tabaci* var. *deformans* H. (*loc. cit.*, 22). Producing exceptionally severe malformation of tomato foliage. (Ainsworth, Ann. Appl. Biol., *24*, 1937, 545–556).

1c. *Marmor tabaci* var. *canadense* H. (*loc. cit.*, 23). Producing a necrotic type of streak disease in tomatoes (Jarrett, Ann. Appl. Biol., *17*, 1930, 248–259).

1d. *Marmor tabaci* var. *lethale* H. (*loc. cit.*, 24). Producing spreading necrotic lesions in tobacco and tomato under experimental conditions (Jensen, Phytopath., *27*, 1937, 69–84; Norval, Phytopath. *28*, 1938, 675–692).

1e. *Marmor tabaci* var. *plantaginis* H. (Phytopath., *31*, 1941, 1097). Specially adapted in nature for systemic spread in species of *Plantago*. This variety contains histidine (0.55 per cent) and methionine (2 per cent) not found in the type of the species.

1f. *Marmor tabaci* var. *obscurum* H. (Handb. Phytopath. Viruses, 1939, 25). Systemic in tobacco without producing obvious disease under experimental conditions (Holmes, Phytopath., *24*, 1934, 845–873; *26*, 1936, 896–904; Jensen, Phytopath., *27*, 1937, 69–84).

1g. *Marmor tabaci* var. *immobile* H. (*loc. cit.*, 26). Produces chlorotic primary lesions in experimentally infected tobacco, but rarely becomes systemic. (Jensen, Phytopath., *23*, 1933, 964–977; *27*, 1937, 69–84).

1h. *Marmor tabaci* var. *artum* H. (*loc. cit.*, 27). Necrotic lesions experimentally induced in *Nicotiana glutinosa* L. (*SOLANACEAE*) are much smaller than those of the type variety (Jensen, Phytopath., *27*, 1937, 69–84).

1i. *Marmor tabaci* var. *siccans* Doolittle and Beecher. (Phytopath., *32*, 1942, 991). Causing necrosis and shriveling of tomato foliage.

2. **Marmor constans** McKinney. (Jour. Washington Acad. Sci., *34*, 1944, 326.) From Latin *constans*, fixed.

Common name: Tobacco mild dark-green mosaic virus.

Hosts: *SOLANACEAE—Nicotiana glauca* R. Grah., tree tobacco.

Insusceptible species: *SOLANACEAE—Lycopersicon esculentum* Mill., tomato. *CUCURBITACEAE—Cucumis sativus* L., cucumber.

Geographical distribution: Islands of Grand Canary and Teneriffe.

Induced disease: In *Nicotiana glauca*, systemic chlorotic mottling.

Transmission: By inoculation of expressed juice. No insect vector is known.

Thermal inactivation: At about 86°C. in 10 minutes.

Literature: McKinney, Jour. Agr. Res., *39*, 1929, 557–578; Am. Jour. Bot., *28*, 1941, 770–778; Peterson and McKinney, Phytopath., *28*, 1938, 329–342; Thornberry and McKinney, *ibid.*, *29*, 1939, 250–260.

3. **Marmor astrictum** Holmes. (Holmes, Handb. Phytopath. Viruses, 1939, 27; *Musivum astrictum* Valleau, Phytopath., *30*, 1940, 823.) From Latin *astrictus*, limited, in reference to host range.

Common names: Cucurbit-mosaic virus, English cucumber-mosaic virus.

Hosts: *CUCURBITACEAE—Cucumis sativus* L., cucumber; *C. anguria* L., gherkin; *C. melo* L., melon; *Citrullus vulgaris* Schrad., watermelon; only cucurbitaceous plants have appeared to be susceptible thus far.

Insusceptible species: All tested solanaceous species. *CUCURBITACEAE—Bryonia dioica* L.; *Cucurbita pepo* L., vegetable marrow. *LEGUMINOSAE—Phaseolus vulgaris* L. var. Golden Cluster.

Geographical distribution: England.

Induced disease: In cucumber, clearing of veins and crumpling in young leaves, followed by a green-mosaic mottling, with blistering and distortion of newly formed leaves. Plant stunted. Fruit unmarked or slightly mottled. Diseased plants less obviously affected during winter months.

Transmission: By inoculation of expressed juice. No insect vector is known.

Serological relationships: Weak cross-precipitin reactions and full cross-neutralization reactions with tobacco-mosaic virus (*Marmor tabaci*). Two common antigens postulated. Preparations of virus that have been inactivated by treatment with nitrous acid or X-rays are still antigenic.

Thermal inactivation: At 80 to 90° C in 10 minutes.

Filterability: Passes Pasteur-Chamberland filters L_1 to L_7, and membranes of 150 millimicrons average pore diameter.

Other properties: Virus, infectious in dilution of 10^{-10}, is present to the extent of 0.2 to 0.3 gram per liter of juice from diseased plants. Preparations show sheen and anisotropy of flow, indicating rod-shaped particles. Solutions stronger than 2.5 per cent separate into 2 layers at room temperature, the lower being the more concentrated and birefringent. Precipitates with ammonium sulfate show needle-shaped paracrystals. Sedimentation constants $S_{20}° = 173 \times 10^{-13}$ cm. sec.$^{-1}$ dyne^{-1} and about 200×10^{-13} cm. sec.$^{-1}$ dyne^{-1}. Virus withstands drying without inactivation but with partial loss of ability to show anisotropy of flow and with reduction of serological activity to about half. Tryptophane content 1.4 per cent, phenylalanine 10.2 per cent, the first lower and the second higher than in tobacco-mosaic virus.

Literature: Ainsworth, Ann. Appl. Biol., *22*, 1935, 55–67; Bawden and Pirie, Nature, *139*, 1937, 546–547; Brit. Jour. Exp. Path., *18*, 1937, 275–291; Knight, Arch. Virusf., *2*, 1942, 260–267; Knight and Stanley, Jour. Biol. Chem., *141*, 1941, 29–38; *141*, 1941, 39–49; Price, Am. Jour. Bot., *27*, 1940, 530–541; Price and Wyckoff, Nature, *141*, 1938, 685.

Strains: A distinctive strain has been distinguished from the type, var. *chlorogenus* H. (*loc. cit.*, 27), by the varietal name:

3a. *Marmor astrictum* var. *aucuba* H. (*loc. cit.*, 29). Differing from the type of this species by inducing a yellow-mottling, rather than a green-mottling, mosaic in cucumber (Ainsworth, Ann. Appl. Biol., *22*, 1935, 55–67).

4. **Marmor laesiofaciens** Zaumeyer and Harter. (Jour. Agr. Res., *67*, 1943, 305.) From Latin *laesio*, substantive from *laedere*, to injure, and participle from *facere*, to make.

Common name: Bean-mosaic virus 4; southern bean mosaic virus 1.

Hosts: *LEGUMINOSAE—Phaseolus vulgaris* L., bean. Experimentally, also *Phaseolus lunatus* L., sieva bean; *Soja max* Piper var. Virginia, Virginia soy bean.

Insusceptible species: All tested species in families other than the *LEGUMINOSAE*.

Geographical distribution: United States (Louisiana).

Induced disease: In bean, systemic chlorotic mottling in some varieties, localized necrosis in others; in a few varieties, systemic necrosis. In mottling-type varieties, chlorotic mottling of foliage; pods marked by dark green blotches or shiny areas, slightly malformed, short, frequently curled at end. In necrotic-type varieties with localized response, bearing a dominant gene lacking in mottling-type varieties, reddish necrotic lesions at the site of inoculation; no evidence of systemic spread of virus. In varieties showing systemic necrosis, pinpoint or slightly larger necrotic primary lesions with veinal necrosis of inoculated leaf; systemic veinal necrosis, distortion and curling of affected leaves, drooping at the pulvini; stem and petiole streak; eventual death of plant.

Transmission: By inoculation of expressed juice. Through seeds from infected plants.

Serological relationships: Not demonstrated.

Immunological relationships: Previous infection with bean-mosaic virus, *Marmor phaseoli*, does not protect against infection with this virus.

Thermal inactivation: At 90 to 95° C, time not stated, probably 10 minutes.

Other properties: Withstands dilution of 1:500,000 and aging 32 weeks at 18° C.

Literature: Zaumeyer and Harter, Phytopath., *32*, 1942, 438–439; *33*, 1943, 16; *34*, 1944, 510–512; Jour. Agr. Res., *67*, 1943, 295–300, 305–328.

Strains: A strain differing from the type has been given the varietal name:

4a. *Marmor laesiofaciens* var. *minus* Zaumeyer and Harter. (Jour. Agr. Res., *67*, 1943, 305.) From Latin *minor*, lesser. Differing from the type by inducing formation of slightly less diffuse and spreading lesions in necrotic-type bean leaves; also by inducing milder early symptoms and more severe late symptoms in mottling-type beans. Passes through seeds from infected plants to infect seedlings grown from them. Found in additional localities in the United States (California, Colorado, Idaho, Maryland).

5. **Marmor lethale** H. (*loc. cit.*, 86). From Latin *lethalis*, causing death.

Common name: Tobacco-necrosis virus.

Hosts: *SOLANACEAE—Nicotiana tabacum* L., tobacco; *N. glutinosa* L.; *N. langsdorffii* Weinm.; *Lycopersicon esculentum* Mill., tomato; *Solanum nigrum* L. *COMPOSITAE*—Aster. *GERANIACEAE—Pelargonium hortorum* Bailey. *LEGUMINOSAE—Phaseolus vulgaris* L., bean. Confined to roots of these natural hosts except in the cases of *Nicotiana tabacum* and *N. glutinosa* in which lower leaves are sometimes invaded; necrotic lesions along midrib and larger veins in these. No obvious manifestations of disease in infected roots. Experimentally to plants in many families with production of localized necrotic lesions only.

Geographical distribution: England, Scotland, Australia. This virus has been found only in greenhouses.

Induced disease: In tobacco, necrosis of midrib and larger veins of first-developed pair of leaves, between November and February. Virus also in roots of many healthy-looking plants throughout the year. Upon artificial inoculation of foliage, numerous small brown necrotic local lesions are produced. Yield of virus from infected plant 0.02 mg per cc of expressed juice, on the average.

Transmission: By contamination of soil with virus. No insect vector is known. Experimentally, by inoculation of expressed juice.

Serological reactions: Precipitates with homologous antiserum. No cross reaction with tomato bushy-stunt or tobacco-mosaic viruses.

Immunological relationships: Protection tests show lack of relationship to tobacco-mosaic virus, tobacco-ringspot virus, tomato-ringspot virus, cucumber-mosaic virus, and the severe-etch strain of tobacco-etch virus.

Thermal inactivation: At 90 to 92° C in 10 minutes.

Filterability: Average particle diameter 20 to 30 millimicrons as determined by filtration through Gradocol membranes; other reports give diameter as 13 to 20 millimicrons by filtration (14 to 19 millimicrons by radiation experiments, about 20 millimicrons from electron micrographs).

Other properties: Infectious after storage for months in dried leaves and after storage for half a year in absolute ethyl alcohol at room temperature. Specific gravity 1.3. More soluble in ammonium sulfate solutions at 0° C than at room temperature. Composition: Carbon 44.8 to 45.3 per cent, nitrogen 15.5 to 16.5 per cent, hydrogen 6.5 to 7.0 per cent, phosphorus 1.4 to 1.7 per cent, sulfur 1.1 to 2.0 per cent, carbohydrate 7.0 to 9.0 per cent; ash 5.8 to 7.0 per cent (3 to 5 per cent after prolonged dialysis at pH 3). Nucleic acid of the ribose type has been isolated. No anisotropy of flow in solution but crystals are birefringent, showing sharp extinctions parallel to, and at right angles to, the plane of the crystal when examined edge-on in a polarizing microscope. Sedimentation constant, $S_{20}° = 112 \times 10^{-13}$; in other preparations a crystalline component with sedimentation constant 130×10^{-13} and an amorphous component with sedimentation constant 58×10^{-13} have been reported, as well as small amounts of a substance with sedimentation constant 220×10^{-13}.

Strains: Isolates of tobacco-necrosis virus serologically distinct but not otherwise different from each other appear to imply the existence of several strains of this virus, or of a closely related group of viruses, in England.

Literature: Bawden, Brit. Jour. Exp. Path., *22*, 1941, 59–70; Bawden et al., *ibid.*, *23*, 1942, 314–328; Cohen, Proc. Soc. Exp. Biol. and Med., *48*, 1941, 163–167; Lea, Nature, *146*, 1940, 137–138; Pirie et al., Parasitol., *30*, 1938, 543–551; Price, Am. Jour. Bot., *25*, 1938, 603–612; Am. Jour. Bot., *27*, 1940, 530–541; Arch. Virusf., *1*, 1940, 373–386; Price and Wyckoff, Phytopath., *29*, 1939, 83–94; Smith, Parasitol., *29*, 1937, 70–85; *29*, 1937, 86–95; Smith and Bald, Parasitol., *27*, 1935, 231–245; Smith and MacClement, Parasitol., *32*, 1940, 320–332.

5a. **Marmor dodecahedron** H. (*loc. cit.*, 30). From Greek *dōdekahedron*, dodecahedron.

Common name: Tomato bushy-stunt virus.

Hosts: *SOLANACEAE—Lycopersicon esculentum* Mill., tomato. Experimentally, also *SOLANACEAE—Datura stramonium* L.; *Nicotiana glutinosa* L.; *N. langsdorffii* Weinm.; *N. tabacum* L., tobacco; *Solanum nigrum* L. *LEGUMINOSAE—Phaseolus vulgaris* L., bean; *Vigna sinensis* (L.) Endl., cowpea. *COMPOSITAE—Zinnia elegans* Jacq., zinnia.

Geographical distribution: British Isles.

Induced disease: In tomato, some primary lesions necrotic, ring-like or spot-like, others masked, or disclosed only by chlorophyll retention in yellowing leaves. In young plants, systemic necrotic lesions may cause death; in older plants, growth ceases, young leaves become pale yellow; growing points may die, inducing growth of axillary buds to produce a bushy top; older leaves become yellowed and show some purple coloration. In White Burley tobacco, local necrosis only, lesions small, red at first, then white. In cowpea, reddish necrotic primary lesions only.

Transmission: By inoculation of expressed juice. Through dodder, *Cuscuta campestris* Yuncker (*CONVOLVULACEAE*). Not through seeds of diseased plants. No insect vector is known.

Serological relationships: A specific antiserum, prepared by a single intravenous injection of rabbits with 2 mg of purified virus, gives granular, compact precipitates, serving for quantitative estimation of this virus, antiserum being used at dilutions of 1:200 or 1:800, virus at dilutions to 10^{-6}.

Immunolcgical relationships: Will infect plants previously invaded by tobacco-mosaic virus, tomato spotted-wilt virus, tobacco-ringspot virus, and Bergerac-ringspot virus.

Filterability: Passes membranes down to 40 millimicrons average pore diameter.

Other properties: Virus crystallizes from solutions of ammonium sulfate as isotropic, rhombic dodecahedra, which shrink and swell reversibly on drying and rewetting; shrinkage reduces size to 80 per cent of the wet dimensions. In the presence of heparin, non-birefringent prisms, rather than dodecahedra, appear. $S_{20}° = 132 \times 10^{-13}$ cm. sec.$^{-1}$ dyne^{-1}. Particle approximately spherical, 27.4 millimicrons in diameter by X-ray measurements (average diameter by filtration data, 14 to 20 millimicrons). Solutions do not show anisotropy of flow. Inactivated by drying. Molecular weight 8,800,000. Density 1.353. Molecular weight may be as high as 24,000,000 in solution, but the density is then lower, 1.286. Analysis: carbon 47 to 50 per cent, nitrogen 15.8 to 16.4 per cent, phosphorus 1.3 to 1.5 per cent, ash 1.7 to 5 per cent, hydrogen 7.2 to 8.2 per cent, sulfur 0.4 to 0.8 per cent, carbohydrate 5 to 6 per cent.

Literature: Ainsworth, Jour. Ministry Agr., *43*, 1936, 266–269; Bawden and Pirie, Nature, *141*, 1938, 513; Brit. Jour. Exp. Path., *19*, 1938, 251–263; Bernal and Fankuchen, Jour. Gen. Physiol., *25*, 1941, 111–165; Bernal et al., Nature, *142*, 1938, 1075; Cohen, Jour. Biol. Chem. *144*, 1942, 353–362; Proc. Soc. Exp. Biol. and Med., *51*, 1942, 104–105; Lauffer, Jour. Phys. Chem., *44*, 1940, 1137–1146; Lauffer and Stanley, Jour. Biol. Chem., *135*, 1940, 463–472; Neurath and Cooper, Jour. Biol. Chem., *135*, 1940, 455–462; Smith, Nature, *135*, 1935, 908; Ann. Appl. Biol., *22*, 1935, 731–741; Jour. Roy. Hort. Soc., *60*, 1935, 448–451; Smith and MacClement, Parasitol., *33*, 1941, 320–330; Stanley, Jour. Biol. Chem., *135*, 1940, 437–454.

Key to the species of the Tobacco-Etch Virus Group.

Viruses relatively susceptible to heat inactivation (inactivated at 52 to 58° C in 10 minutes). A small, closely allied group, tending to replace or to be replaced by each other, if present in mixture in tobacco.

I. Not replaced, if in mixture, by other viruses of this group; dominant member of the group in tobacco.
   6. *Marmor erodens.*

II. Replaced by No. 6, not by No. 8, if in mixture with it in tobacco.
   7. *Marmor hyoscyami.*

III. Replaced by No. 6 or 7 if in mixture with either in tobacco.
   8. *Marmor upsilon.*

6. **Marmor erodens** Holmes. (Holmes, Handb. Phytopath. Viruses, 1939, 40; *Foliopellis erodens* Valleau, Phytopath., *30*, 1940, 825.) From Latin *erodere*, to erode or gnaw away.

Common name: Tobacco-etch virus.

Hosts: *SOLANACEAE—Capsicum frutescens* L., pepper; *Datura stramonium* L., Jimson weed; *Lycopersicon esculentum* Mill., tomato; *Nicotiana tabacum* L., tobacco; *Petunia* sp., petunia; *Physalis heterophylla* Nees.

Geographical distribution: United States.

Induced disease: In tobacco, systemic mild-mottling chlorosis, with traces of necrotic etching; intranuclear crystalline inclusions and intracytoplasmic granular and amorphous inclusions that tend to crystallize, forming needle-shaped birefringent bodies, 2 to 10 microns in length.

Transmission: Experimentally, by *Myzus persicae* (Sulz.), *M. circumflexus* (Buckt.), *Aphis rhamni* Boyer, *A. fabae* (Scop.), and *Macrosiphum gei* (Koch) (*APHIDIDAE*); by inoculation of expressed juice.

Serological relationships: Precipitin reactions with homologous antisera, but no cross-reactions with tobacco-mosaic virus, tobacco-ringspot virus, potato-mottle virus, potato aucuba-mosaic virus, potato mild-mosaic virus, hyoscyamus-mosaic virus, potato-veinbanding virus, or pea-mosaic virus.

Immunological relationships: Protects tobacco against subsequent infection by potato-veinbanding virus and hyoscyamus-mosaic virus. In mixed infections, it suppresses and replaces these two viruses.

Thermal inactivation: At 53 to 55° C in 10 minutes.

Filterability: Passes Pasteur-Chamberland L_1, not L_3, filter candle.

Other properties: Sedimentation constant $S_{20}° = 170 \times 10^{-13}$ cm. sec.$^{-1}$ dyne^{-1}. Concentrated preparations show anisotropy of flow, indicating elongated particle shape.

Literature: Bawden and Kassanis, Ann. Appl. Biol., *28*, 1941, 107–118; Fernow, Cornell Agr. Exp. Sta. (Ithaca), Mem. 96, 1925; Holmes, Phytopath., *32*, 1942, 1058–1067; Johnson, Kentucky Agr. Exp. Sta., Res. Bull. 306, 1930.

Strains: A distinctive severe-symptom strain, isolated from plants infected in nature and studied intensively, has been distinguished from the type, var. *vulgare* H. (*loc. cit.*, 40), by the varietal name:

6a. *Marmor erodens* var. *severum* H. (*loc. cit.*, 41). Differing from the type by a tendency to induce more pronounced necrotic etching and a greater stunting effect in infected tobacco.

7. **Marmor hyoscyami** *spec. nov.* From New Latin *Hyoscyamus*, genus name of plant from which this virus was first isolated.

Common names: Hyoscyamus-mosaic virus, Hy. III virus, Hyoscyamus-III-disease virus.

Hosts: *SOLANACEAE—Hyoscyamus niger* L., henbane. Experimentally, also *Nicotiana tabacum* L., tobacco.

Insusceptible species: *CUCURBITACEAE—Cucumis sativus* L., cucumber.

Geographical distribution: England.

Induced disease: In henbane, chlorotic clearing of veins followed by yellow-mottling mosaic.

Transmission: By inoculation of expressed juice to dilutions of 10^{-4}. By aphids, *Myzus persicae* (Sulz.), *M. circumflexus* (Buckt.), and *Macrosiphum solanifolii* Ashm. (= *M. gei* Koch) (*APHIDIDAE*).

Serological relationships: Several isolates of this virus give mutual cross-precipitin reactions but no precipitation occurs when antiserum prepared with this virus is mixed with cucumber-mosaic virus, tobacco-etch virus, or potato-veinbanding virus.

Immunological relationships: No immunity with respect to this virus is induced in tobacco by previous infection with cucumber-mosaic virus. Potato-veinbanding virus is unable to multiply in the presence of this virus and is replaced by it. Tobacco-etch virus pro-

tects against this virus and replaces it in mixed infections.

Thermal inactivation: At 58° C in 10 minutes.

Filterability: Passes Chamberland L_1, but not L_3, filter candles.

Other properties: Concentrated solutions show anisotropy of flow. Yield of virus, 1 to 3 mg per liter of juice expressed from diseased tobacco plants.

Literature: Bawden and Kassanis, Ann. Appl. Biol., *28*, 1941, 107–118; Hamilton, *ibid.*, *19*, 1932, 550–567; Sheffield, *ibid.*, *25*, 1938, 781–789; Watson and Roberts, Proc. Roy. Soc. London, Ser. B, *127*, 1939, 543–576.

8. **Marmor upsilon** *comb. nov.* (*Marmor cucumeris* var. *upsilon* Holmes, *loc. cit.*, 33; *Murialba venataenia* Valleau, Phytopath., *30*, 1940, 824.) From Greek name of the letter Y, sometimes used to denote this virus.

Common names: Potato-veinbanding virus, potato virus Y.

Hosts: *SOLANACEAE—Solanum tuberosum* L., potato; *Nicotiana tabacum* L., tobacco. Experimentally, also *Lycium barbarum* L.

Geographical distribution: England, France, United States, Brazil. Rare in Scotland and part of Ireland.

Induced disease: In some potato varieties, leaf drop and necrotic stem-streak; in others, no signs of disease; in still others, chlorotic mottling with or without necrosis. In combination with strains of the potato-mottle virus (*Marmor dubium*), this virus causes rugose mosaic, a common and destructive double-virus disease.

Transmission: By inoculation of expressed juice. By aphid, *Myzus persicae* (Sulz.); experimentally, also by *Aphis rhamni* Boyer (synonym for *Aphis abbreviata* Patch) (*APHIDIDAE*).

Serological relationships: Precipitin reactions with homologous antisera. No cross reactions with tobacco-mosaic virus, tobacco-etch virus, hyoscyamus-mosaic virus, potato-mottle virus, potato mild-mosaic virus, potato aucuba-mosaic virus, tobacco-ringspot virus, or common pea-mosaic virus. Reported cross reaction with cucumber-mosaic virus needs confirmation.

Immunological relationships: A mild strain protects against subsequent infection with the typical virus. This virus is suppressed and replaced by hyoscyamus-mosaic virus and by tobacco-etch virus in mixed infections.

Thermal inactivation: At 52° C in 10 minutes.

Filterability: Passes with difficulty through Gradocol membrane of 42 millimicron average pore diameter.

Other properties: Inactivated by drying.

Literature: Dennis, Nature, *142*, 1938, 154; Johnson, Phytopath., *25*, 1935, 650–652; Jones and Vincent, Jour. Agr. Res., *55*, 1937, 69–79; Kassanis, Ann. Appl. Biol., *29*, 1942, 95; Koch, Phytopath., *23*, 1933, 319–342; Kramer and Silberschmidt, Arquivos Inst. Biol., São Paulo, Brazil, *11*, 1940, 165–188; Salaman, Nature, *139*, 1937, 924; Smith, Proc. Roy. Soc., Ser. B, *109*, 1931, 251–267; Smith and Dennis, Ann. Appl. Biol., *27*, 1940, 65–70.

Key to the species of the Cucumber-Mosaic Virus Group.

Viruses relatively susceptible to heat inactivation, requiring less than 10 minutes at 85 to 90° C for complete inactivation. Not replacing potato-veinbanding virus in mixed infections.

I. Infecting both dicotyledonous and monocotyledonous plants.

9. *Marmor cucumeris.*

II. Infecting dicotyledonous, but not monocotyledonous, plants.

10. *Marmor solani.*

11. *Marmor aucuba.*

12. *Marmor umbelliferarum.*

13. *Marmor cruciferarum.*
14. *Marmor brassicae.*
15. *Marmor betae.*
16. *Marmor lactucae.*
17. *Marmor dahliae.*
18. *Marmor phaseoli.*
19. *Marmor leguminosarum.*
20. *Marmor pisi.*
21. *Marmor medicaginis.*

III. Infecting monocotyledonous, but not dicotyledonous, plants.

22. *Marmor tulipae.*
23. *Marmor mite.*
24. *Marmor iridis.*
25. *Marmor sacchari.*
26. *Marmor cepae.*
27. *Marmor scillearum.*

9. **Marmor cucumeris** Holmes. (Holmes, Handb. Phytopath. Viruses, 1939, 31; *Murialba cucumeris* Valleau, Phytopath., *30*, 1940, 823.) From Latin *cucumis*, cucumber.

Common name: Cucumber-mosaic virus.

Hosts: Very wide range of hosts among dicotyledonous and monocotyledonous plants; cucumber, celery, spinach, tobacco, and pepper are sometimes seriously affected. Overwintering hosts are: *SOLANACEAE—Physalis subglabrata* Mackenzie and Bush, *P. heterophylla* Nees. *ASCLEPIADACEAE—Asclepias syriaca* L. *PHYTOLACCACEAE—Phytolacca decandra* L. *LABIATAE—Nepeta cataria* L. Probably there are also other susceptible perennials.

Geographical distribution: Probably almost world-wide.

Induced disease: In cucumber, *Cucumis sativus* L., yellowish-green systemic mottling. Leaves small, distorted, curled; plants dwarfed, internodes shortened. Few fruits set. Fruits mottled, misshapen, giving the disease the name "white pickle." In black cowpea, *Vigna sinensis* (L.) Endl., small reddish necrotic local lesions only. No intracellular bodies are found in plants infected with cucumber-mosaic virus.

Transmission: By inoculation of expressed juice. By aphids, *Myzus persicae* (Sulz.), *M. pseudosolani* Theob., *M. circumflexus* (Buckt.), *Macrosiphum solanifolii* Ashm., and *Aphis gossypii* Glov. (*APHIDIDAE*). Through seeds of diseased plants in *Echinocystis lobata* (Michx.) Torr. and Gray, wild cucumber, in *Cucumis melo* L., muskmelon, and in *Cucurbita pepo* L., vegetable marrow. By several species of dodder, *Cuscuta californica* Choisy, *C. campestris* Yuncker, and *C. subinclusa* Dur. and Hilg. (*CONVOLVULACEAE*).

Immunological relationships: Infection with the type and other chlorotic-mottling strains protects zinnia against subsequent infection by an indicator strain of this virus (var. *judicis*).

Thermal inactivation: At 70 to 80° C in 10 minutes.

Filterability: Passes Berkefeld W and N filters and collodion membranes of 45 millimicron average pore diameter.

Other properties: Inactivated by drying or 3 to 4 days' storage in juice at room temperature.

Literature: Ainsworth, Ann. Appl. Biol., *25*, 1938, 867–869; Chamberlain, New Zealand Jour. Science and Technology, *21*, 1939, 73A–90A; Celino, Philippine Agr., *29*, 1940, 379–414; Doolittle, Phytopath., *6*, 1916, 145–147; U. S. Dept. Agr., Bull. 879, 1920; Doolittle and Walker, Jour. Agr. Res., *31*, 1925, 1–58; Gilbert, Phytopath., *6*, 1916, 143–144; Hoggan, Jour. Agr. Res., *47*, 1933, 689–704; Jagger, Phytopath., *6*, 1916, 148–151;

8, 1918, 32–33; Kendrick, Phytopath., *24*, 1934, 820–823; Mahoney, Proc. Am. Soc. Hort. Sci., *332*, 1935, 477–480; Price, Phytopath., *25*, 1935, 776–789; *29*, 1939, 903–905; Am. Jour. Bot., *27*, 1940, 530–541; Storey, Ann. Appl. Biol., *26*, 1939, 298–308.

Strains: Various host plants seem to have induced specialization of cucumber-mosaic virus in strains particularly adapted to existence in their tissues. Several of these and certain laboratory-derived strains useful in technical procedures have been distinguished from the type, var. *vulgare* H. (*loc. cit.*, 31), by varietal names, as follows:

9a. *Marmor cucumeris* var. *commelinae* H. (*loc. cit.*, 35). From New Latin *Commelina*, generic name of weed serving as a natural reservoir of this strain. Common name: Southern celery-mosaic strain of cucumber-mosaic virus. Differing from the type in severity of disease induced in celery and some other plants. Transmitted by *Aphis gossypii* Glov., *A. maidis* Fitch, and *Pentalonia nigronervosa* Coq. (*APHIDIDAE*). (Price, Phytopath., *25*, 1935, 947–954; Wellman, *ibid.*, *24*, 1934, 695–725, 1032–1037; *25*, 1935, 289–308, 377–404.)

9b. *Marmor cucumeris* var. *phaseoli* H. (*loc. cit.*, 36). From New Latin *Phaseolus*, generic designation of lima bean. Common name: Lima-bean strain of cucumber-mosaic virus. Differing from type of species in ability to cause a chlorotic mottling disease in lima bean in nature. (Harter, Phytopath., *26*, 1936, 94; Jour. Agr. Res., *56*, 1938, 895–906; McClintock, Phytopath., *7*, 1917, 60.)

9c. *Marmor cucumeris* var. *lilii* H. (*loc. cit.*, 37). From Latin *lilium*, lily. Common name: Lily-mosaic strain of cucumber-mosaic virus. Differing from the type variety by ability to persist in nature in lilies, producing masked infection or chlorotic mottling unless in mixture with lily-symptomless virus (*Adelonosus lilii*), when a more severe disease involving necrosis is induced. (Brierley, Phytopath., *29*, 1939, 3; *30*, 1940, 250–257; Brierley and Doolittle, *ibid.*, *30*, 1940, 171–174; Ogilvie and Guterman, *ibid.*, *19*, 1929, 311–315; Price, *ibid.*, *27*, 1937, 561–569.)

9d. *Marmor cucumeris* var. *judicis* H. (*loc. cit.*, 38). From Latin *judex*, judge. Common name: Indicator strain of cucumber-mosaic virus. Differing from the type variety in inducing the formation of necrotic local lesions in zinnia (*Zinnia elegans* Jacq., *COMPOSITAE*). Previous infection of zinnia by other strains of cucumber-mosaic virus inhibits the formation of these necrotic local lesions, identifying the strains as related to each other and to the indicator strain. (Price, Phytopath., *24*, 1934, 743–761; *25*, 1935, 776–789.)

9e. *Marmor cucumeris* var. *vignae* H. (*loc. cit.*, 39). From New Latin *Vigna*, generic name of cowpea. Common name: Cowpea-mottling strain of cucumber-mosaic virus. Differing from the type variety in producing systemic chlorotic mottling, rather than reddish-brown necrotic local lesions, in Black cowpea. Not known in nature but derived experimentally from a mild-mottling strain of cucumber-mosaic virus during serial passage in cowpea. (Price, Phytopath., *24*, 1934, 743–761; *25*, 1935, 776–789.)

10. **Marmor solani** H. (*loc. cit.*, 47). From New Latin *Solanum*, generic name of potato.

Common names: Potato mild-mosaic virus, potato virus A.

Hosts: *SOLANACEAE—Solanum tuberosum* L., potato. Experimentally, also *Nicotiana tabacum* L., tobacco; *Solanum nigrum* L. var. *nodiflorum*; and *Datura stramonium* L., Jimson weed.

Geographical distribution: United States, England, Holland.

Induced disease: In potato, very mild chlorotic mottling or masked symptoms in some varieties (as Irish Chieftain), systemic necrosis in others (for example,

British Queen). Immunity to aphid infection with this virus is found in the varieties Katahdin and Earlaine. A combination disease, characterized by pronounced yellow-mosaic patterns, is caused by this virus in the variety Irish Chieftain if the potato-veinbanding virus (*Marmor upsilon*) is also present. In tobacco, experimentally, faint veinbanding mosaic.

Transmission: To potato, by rubbing methods of inoculation of expressed juice, using carborundum powder; to tobacco, by rubbing without carborundum. By aphids, *Aphis abbreviata* Patch and *Myzus persicae* (Sulz.) (*APHIDIDAE*).

Serological relationships: No cross-precipitin reactions with potato aucuba-mosaic virus, potato-veinbanding virus, tobacco-mosaic virus, tobacco-etch virus, tobacco-ringspot virus, or pea-mosaic virus.

Immunological relationships: A feeble strain of this virus has been found to protect fully against the typical strain in the Netherlands.

Thermal inactivation: At 50° C in 10 minutes.

Literature: Bawden, Ann. Appl. Biol., *23*, 1936, 487–497; Chester, Phytopath., *25*, 1935, 686–701; Dykstra, Phytopath., *29*, 1939, 40–67; Hansen, Tidsskr. Planteavl, *42*, 1937, 631–681; Murphy and Loughnane, Sci. Proc. Roy. Dublin Soc., *21*, 1936, 419–430; Murphy and McKay, *ibid.*, *20*, 1932, 227–247; Oortwijn Botjes, Tijdsch. Plantenziekten, *45*, 1939, 25–29; Schultz *et al.*, Phytopath., *27*, 1937, 190–197; *30*, 1940, 944–951.

11. **Marmor aucuba** H. (*loc. cit.*, 49). From New Latin *Aucuba*, a genus of plants having mottled foliage.

Common name: Potato aucuba-mosaic virus.

Hosts: *SOLANACEAE—Solanum tuberosum* L., potato. Experimentally, also *Atropa belladonna* L. (symptomless); *Capsicum frutescens* L., pepper; *Datura stramonium* L., Jimson weed (symptomless); *Hyoscyamus niger* L., henbane (symptomless); *Lycopersicon esculentum* Mill., tomato; *Petunia hybrida* Vilm., *petunia* (symptomless); *Nicotiana tabacum* L., tobacco (symptomless); *Solanum dulcamara* L., bittersweet; *S. nigrum* L. var. *nodiflorum*.

Geographical distribution: United States, Great Britain, Europe.

Induced disease: In potato, yellow spots on lower leaves of some varieties; in the variety Irish Chieftain, brilliant yellow mottle over whole plant, perhaps because of simultaneous presence of potato mild-mosaic virus in this variety. Necrosis of the cortex and of the pith in tubers in many varieties.

Transmission: By inoculation of expressed juice. Probably by aphid, *Myzus persicae* (Sulz.) (*APHIDIDAE*).

Serological relationships: No precipitin cross-reactions with potato mild-mosaic virus, potato-veinbanding virus, tobacco-mosaic virus, tobacco-etch virus, tobacco-ringspot virus, or pea-mosaic virus. Precipitin cross-reactions with the Canada-streak strain of potato aucuba-mosaic virus.

Thermal inactivation: At 65 to 68° C in 10 minutes.

Filterability: Passes Pasteur-Chamberland L_1 filter, but not L_3 or L_5.

Literature: Chester, Phytopath., *25*, 1935, 686–701; *27*, 1937, 903–912; Clinch, Sci. Proc. Roy. Dublin Soc., *22*, 1941, 435–445; Clinch et al., *ibid.*, *21*, 1936, 431–448; Dykstra, Phytopath., *29*, 1939, 917–933.

Strains: One strain differing from the type has been given a varietal name:

11a. *Marmor aucuba* var. *canadense* Black and Price. (Phytopath. *30*, 1940, 444.) From common name of strain.

Common name: Canada-streak strain of potato aucuba-mosaic virus. Differing from the type variety by tendency to produce necrosis in stems, veins, petioles, and leaves and also, about 2 months after harvest, in pith of tuber, especially at stem end. (Chester, Phytopath., *27*,

1937, 903–912; Dykstra, Phytopath., *29*, 1939, 917–933.)

12. **Marmor umbelliferarum** H. (*loc. cit.*, 67). From New Latin *Umbelliferae*, family name of plants among which celery is classified.

Common name: Celery-mosaic virus, western celery-mosaic virus.

Hosts: *UMBELLIFERAE—Apium graveolens* L., celery and celeriac; *Daucus carota* L., carrot. Experimentally, also *Anethum graveolens* L., dill; *Anthriscus cerefolium* (L.) Hoffm., salad chervil; *Carum carvi* L., caraway; *Coriandrum sativum* L., coriander; *Petroselinum hortense* Hoffm., parsley.

Insusceptible species: *Cucumis sativus* L., cucumber, and all other tested species not of the family *Umbelliferae.*

Geographical distribution: United States (California).

Induced disease: In celery, at first, clearing of veins in young leaves; later, foliage yellowed, plant stunted, young petioles shortened, older petioles horizontal, giving plant a flat appearance. Foliage mottled green and yellow; leaflets narrow, twisted or cupped; older leaves with some necrosis; petioles with white streaks or spots. In celeriac, clearing of veins, followed by systemic chlorotic mottling. In carrot, chlorotic spotting of young leaves, followed by systemic chlorotic mottling.

Transmission: By inoculation of expressed juice, in dilutions to 1:4000. No specific insect vector is known, but 11 species of aphids capable of breeding on celery transmit the virus, though they do not long retain the power of transmission after leaving diseased plants. These vectors are *Aphis apigraveolens* Essig, *A. apii* Theob., *A. ferruginea-striata* Essig, *A. gossypii* Glov., *A. middletonii* Thomas, *A. rumicis* Linn., *Cavariella capreae* (Fabr.), *Myzus circumflexus* (Buckt.), *M. convolvuli* (Kalt.), *M. persicae* (Sulz.), *Rhopalosiphum melliferum* (Hottes) (*APHIDIDAE*). Some aphids not able to breed on celery also transmit this virus.

Thermal inactivation: At 55 to 60° C in 10 minutes.

Filterability: Passes all grades of Chamberland filters.

Other properties: Virus active after storage at −18° C for 18 months.

Literature: Severin and Freitag, Hilgardia, *11*, 1938, 493–558.

13. **Marmor cruciferarum** H. (*loc. cit.*, 69). From New Latin *Cruciferae*, family name of plants among which cauliflower is classified.

Common name: Cauliflower-mosaic virus.

Hosts: *CRUCIFERAE—Brassica oleracea* L., cauliflower, kale, Brussels sprouts, cabbage, and broccoli; *B. campestris* L., wild yellow mustard; *Matthiola incana* R. Br., annual stock. Experimentally, also *Brassica adpressa* Boiss; *B. alba* Rabenh., white mustard; *B. arvensis* (L.) Ktze., charlock; *B. juncea* Coss., leaf mustard (one strain not susceptible); *B. napus* L., rape; *B. pe-tsai* Bailey, pe-tsai; *B. nigra* Koch, black mustard; *B. rapa* L., turnip; *Capsella bursa-pastoris* Medic., shepherd's purse; *Iberis amara* L., rocket candytuft; *Lepidium sativum* L., garden cress; *Lunaria annua* L., honesty; *Raphanus raphanistrum* L., white charlock; *R. sativus* L., radish.

Insusceptible species: *CHENOPODIACEAE—Spinacia oleracea* L. *COMPOSITAE—Lactuca sativa* L. *CRUCIFERAE—Alyssum saxatile* L.; *A. maritimum* Lam.; *Arabis albida* Stev.; *Athysanus pusillus* Greene; *Brassica juncea* Coss. (Japanese strain; another strain susceptible); *Cheiranthus cheiri* L.; *Erysimum perofskianum* Fisch. and Mey.; *Hesperis matronalis* L.; *Malcomia maritima* R. Br.; *Roripa nasturtium* Rusby; *Stanleya pinnata* (Pursh.) Britt.; *Thysanocarpus radians* Benth. *LEGUMINOSAE—Vicia faba* L. *SOLANACEAE—Capsicum frutescens* L.; *Lycoper-*

sicon esculentum Mill.; *L. pimpinellifolium* Mill.; *Nicotiana glutinosa* L.; *N. langsdorffii* Weinm.; *N. tabacum* L. vars. Turkish and White Burley. *TROPAEOLACEAE—Tropaeolum majus* L. *UMBELLIFERAE—Apium graveolens* L.

Geographical distribution: United States, England.

Induced disease: In cauliflower, clearing of veins, followed by mild chlorotic mottling, veins usually banded with dark green, necrotic flecks later in chlorotic areas. Midrib curved, leaves distorted. Plant stunted; terminal head or curd dwarfed. Solanaceous plants appear to be immune, a point of distinction between this virus and turnip-mosaic virus, *Marmor brassicae*.

Transmission: By inoculation of expressed juice, using carborundum powder. By many aphid species, *Brevicoryne brassicae* (Linn.), cabbage aphid; *Rhopalosiphum pseudobrassicae* Davis, false cabbage aphid; *Myzus persicae* (Sulz.), peach aphid; *Aphis graveolens* Essig, celery leaf aphid; *A. apigraveolens* Essig, celery aphid; *A. middletonii* Thomas, erigeron root aphid; *A. gossypii* Glov., cotton aphid; *Cavariella capreae* (Fabr.), yellow willow aphid; *Myzus circumflexus* (Buckt.), lily aphid; *Rhopalosiphum melliferum* (Hottes), honeysuckle aphid. (*APHIDIDAE*). No seed transmission.

Thermal inactivation: At 75° C in 10 minutes.

Literature: Caldwell and Prentice, Ann. Appl. Biol., *29*, 1942, 366–373, 374–379; Rawlins and Tompkins, Phytopath., *24*, 1934, 1147 (Abst.); Tompkins, Jour. Agr. Res., *55*, 1937, 33–46.

14. Marmor brassicae H. (H., *loc. cit.*, 70; *Marmor matthiolae* H., *loc. cit.*, 71.) From New Latin, *Brassica*, generic name of turnip.

Common name: Turnip-mosaic virus.

Hosts: *CRUCIFERAE—Brassica rapa* L., turnip; *B. napobrassica* Mill., swede or rutabaga; *B. napus* L., rape; *B. nigra* (L.) Koch, black mustard; *B. oleracea* L., cabbage; *Armoracia rusticana* Gaertn., horse-radish; *Cheiranthus cheiri* L., wallflower; *Matthiola incana* R. Br., stock; *Sinapis alba* L., white mustard. Experimentally, also *CRUCIFERAE—Berteroa incana* (L.) DC.; *Brassica alba* Rabenh., white mustard; *B. arvensis* (L.) Ktze.; *B. chinensis* L., Chinese cabbage; *B. juncea* (L.) Coss.; *Capsella bursa-pastoris* (L.) Medic.; *Cardamine heterophylla* (Forst. f.) O. E. Schultz; *Cheiranthus allionii* Hort.; *Coronopus didymus* Smith; *Hesperis matronalis* L.; *Lepidium ruderale* L.; *L. sativum* L., *L. virginicum* L.; *Nasturtium officinale* R. Br.; *Neslia paniculata* (L.) Desv.; *Radicula palustris* (L.) Moench.; *Raphanus sativus* L.; *Sisymbrium altissimum* L.; *S. officinale* (L.) Scop.; *Thlaspi arvense* L. *CHENOPODIACEAE—Beta vulgaris* L.; *Spinacia oleracea* L., spinach. *COMPOSITAE—Calendula officinalis* L. *Zinnia elegans* Jacq. *RANUNCULACEAE—Delphinium ajacis* L. *SOLANACEAE—Lycopersicon pimpinellifolium* Mill.; *Nicotiana bigelovii* S. Wats.; *N. glutinosa* L.; *N. langsdorffii* Weinm.; *N. repanda* Willd.; *N. rustica* L.; *N. sylvestris* Speg. and Comes; *N. tabacum* L., tobacco; *Petunia hybrida* Vilm.

Geographical distribution: United States, England, New Zealand.

Induced disease: In turnip, systemic chlorotic mottling; plants stunted, leaves distorted. In tobacco, experimentally, characteristic necrotic primary lesions only.

Transmission: By inoculation of expressed juice. By cabbage aphid, *Brevicoryne brassicae* (Linn.), and by the peach aphid, *Myzus persicae* (Sulz.) (*APHIDIDAE*).

Thermal inactivation: At 54° C in 10 minutes.

Strains: A considerable number of strains of this virus appear to occur in nature, but those that have been studied often have been considered as distinct viruses and not compared with each other

under identical circumstances. More work is needed to show existing alliances.

Literature: Chamberlain, New Zealand Jour. Agr., *53*, 1936, 321–330; New Zealand Jour. Science and Technology, *21*, 1939, 212A–223A; Clayton, Jour. Agr. Res., *40*, 1930, 263–270; Gardner and Kendrick, *ibid.*, *22*, 1921, 123–124; Hoggan and Johnson, Phytopath., *25*, 1935, 640–644; Larson and Walker, Jour. Agr. Res., *59*, 1939, 367–392; *62*, 1941, 475–491; Schultz, Jour. Agr. Res., *22*, 1921, 173–178; Smith, Ann. Appl. Biol., *22*, 1935, 239–242; Tompkins, Jour. Agr. Res., *57*, 1938, 589–602; *58*, 1939, 63–77; Tompkins *et al.*, *ibid.*, *57*, 1938, 929–943.

15. **Marmor betae** H. (*loc. cit.*, 72). From Latin *beta*, beet.

Common name: Sugar-beet mosaic virus.

Hosts: *CHENOPODIACEAE—Beta vulgaris* L., beet; *Spinacia oleracea* L., spinach.

Geographical distribution: France, Denmark, Germany, Sweden, United States, England.

Induced disease: In beet, discrete yellowish secondary lesions or clearing of veins on young leaves, followed by chlorotic mottling of newly formed leaves. Darkening of vascular tissue. Leaves bend back near tips, which sometimes die. Intracellular bodies formed. In spinach, 6 to 21 days after infection, chlorotic flecks on young leaves. Plant stunted, outer leaves killed, dying from their tips back. Center of plant survives for a time, but finally dies.

Transmission: By inoculation of expressed juice, in dilutions to 10^{-3}. By aphids, *Myzus persicae* (Sulz.), *Aphis rumicis* Linn., and perhaps *Macrosiphum solanifolii* Ashm. (= *M. gei* Koch) (*APHIDIDAE*). No seed transmission.

Thermal inactivation: At 55 to 60° C in 10 minutes.

Other properties: Inactivated by standing in expressed juice for 24 to 48 hours at about 70° F.

Literature: Böning, Forsch. Geb. Pflanzenkr. u. Immun. Pflanzenreich, *3*, 1927 81–128; Cent. f. Bakt., II Abt., *71*, 1927, 490–497; Gratia and Manil, Compt. rend. Soc. Biol., Paris, *118*, 1935, 379–381; Hoggan, Phytopath., *23*, 1933, 446–474; Jones, Washington Agr. Exp. Sta. Bull. 250, 1931; Lind, Tidsskr. Planteavl, *22*, 1915, 444–457; Robbins, Phytopath., *11*, 1921, 349–365; Schmidt, Ber. Deutsch. Bot. Ges., *45*, 1927, 598–601.

16. **Marmor lactucae** H. (*loc. cit.*, 84). From Latin *lactuca*, lettuce.

Common name: Lettuce-mosaic virus.

Hosts: *COMPOSITAE—Lactuca sativa* L., lettuce; *Senecio vulgaris* L., groundsel. Experimentally, also *COMPOSITAE—Sonchus asper* Hoffm., prickly sow-thistle. *LEGUMINOSAE—Lathyrus odoratus* L., sweet pea; *Pisum sativum* L., pea.

Insusceptible species: *COMPOSITAE—Sonchus oleraceus* L., *S. arvensis* L., *Taraxacum officinale* Web., *Carduus arvensis* Curt. *CRUCIFERAE—Brassica oleracea* L. *CUCURBITACEAE—Cucumis sativus* L. *SOLANACEAE—Lycopersicon esculentum* Mill., *Nicotiana tabacum* L., *N. glutinosa* L., *Datura stramonium* L.

Geographical distribution: United States, England, Germany, Bermuda.

Induced disease: In lettuce varieties, clearing of veins followed by systemic chlorotic mottling, dwarfing and defective hearting; sometimes by scorching of leaf edges, vein necrosis or necrotic flecking between veins.

Transmission: By inoculation of expressed juice, in dilutions to 1:100 if mixed with a little 0.5 per cent sodium sulphite solution and a trace of powdered carborundum. By aphids, *Myzus persicae* (Sulz.) and *Macrosiphum gei* Koch (*APHIDIDAE*). Through seeds from diseased plants. It is believed that seed-borne virus is the most important source of primary inoculum in the spring.

Thermal inactivation: At 55 to 60° C in 10 minutes.

Filterability: Fails to pass L_1 Pasteur-Chamberland filter.

Literature: Ainsworth and Ogilvie, Ann. Appl. Biol., *26*, 1939, 279–297; Jagger, Jour. Agr. Res., *20*, 1921, 737–740; Newhall, Phytopath., *13*, 1923, 104–106.

17. **Marmor dahliae** H. (*loc. cit.*, 85). From New Latin *Dahlia*, generic name of host plant.

Common name: Dahlia-mosaic virus.

Hosts: *COMPOSITAE—Dahlia pinnata* Cav., dahlia. Experimentally, also *D. imperialis* Roezl.; *D. maxonii* Safford.

Geographical distribution: United States, Holland, Germany, England.

Induced disease: In intolerant varieties of dahlia, chlorotic mottling of foliage, leaf distortion, dwarfing of all stems and of roots, occasionally necrotic streaking of midveins. In tolerant varieties, inconspicuous chlorotic mottling or masked symptoms.

Transmission: By aphid, *Myzus persicae* (Sulz.) (*APHIDIDAE*). By grafting. Not by inoculation of expressed juice. Not through soil. Not through seeds from diseased plants.

Literature: Brierley, Am. Dahlia Soc. Bull., Ser. 9, No. 65, 1933; Contrib. Boyce Thompson Inst., *5*, 1933, 235–288; Goldstein, Bull. Torrey Bot. Club, *54*, 1927, 285–293.

18. **Marmor phaseoli** H. (*loc. cit.*, 87). From New Latin *Phaseolus*, generic name of bean.

Common name: Bean-mosaic virus.

Hosts: *LEGUMINOSAE—Phaseolus vulgaris* L., bean. Experimentally, also *Phaseolus acutifolius* Gray var. *latifolius* Freem.; *P. aureus* Roxb.; *P. calcaratus* Roxb.; *P. lunatus* L.; *Lespedeza striata* (Thunb.) Hook. and Arn.; *Vicia faba* L.; *V. sativa* L., spring vetch.

Insusceptible species: *LEGUMINOSAE—Pisum sativum* L., garden pea; *Lathyrus odoratus* L., sweet pea.

Geographical distribution: World-wide, wherever beans are grown.

Induced disease: In bean, first leaves to be affected are crinkled, stiff, chlorotic; later leaves show chlorotic mottling; leaf margins often rolled down. Optimum temperature for expression of disease, 20 to 28° C, partial masking at 28 to 32° C, complete masking at 12 to 18° C.

Transmission: By inoculation of expressed juice in dilutions to 1:1000, using carborundum or other abrasive powder. By aphids, *Aphis rumicis* Linn., *Macrosiphum* (= *Illinoia*) *solanifolii* Ashm., *M. pisi* Kalt., *Aphis gossypii* Glov., *A. medicaginis* Koch, *A. spiraecola*, *Brevicoryne brassicae* (Linn.), *Hyalopterus atriplicis* Linn., *Macrosiphum ambrosiae* Thos., *Rhopalosiphum pseudobrassicae* Davis, and *Myzus persicae* (Sulz.) (*APHIDIDAE*). In beans, there is seed transmission to 30 to 50 per cent of plants grown from infected parents; pollen from infected plants is said to transmit virus.

Thermal inactivation: At 56 to 58° C in 10 minutes.

Literature: Fajardo, Phytopath., *20*, 1930, 469–494, 883–888; Murphy, *ibid.*, *30*, 1940, 779–784; Murphy and Pierce, *ibid.*, *28*, 1938, 270–273; Parker, Jour. Agr. Res., *52*, 1936, 895–915; Pierce, Phytopath., *24*, 1934, 87–115; Jour. Agr. Res., *49*, 1934, 183–188; *51*, 1935, 1017–1039; Reddick, II Congr. Intern. Path. Comp., 1931, 363–366; Reddick and Stewart, Phytopath., *8*, 1918, 530–534; Richards and Burkholder, Phytopath., *33*, 1943, 1215–1216; Wade and Andrus, Jour. Agr. Res., *63*, 1941, 389–393; Wade and Zaumeyer, U. S. Dept. Agr., Circ. 500, 1938; Walker and Jolivette, Phytopath., *33*, 1943, 778–788; Zaumeyer and Kearns, *ibid.*, *26*, 1936, 614–629; Zaumeyer and Wade, Jour. Agr. Res., *51*, 1935, 715–749.

19. **Marmor leguminosarum** H. (*loc. cit.*, 89). From New Latin *Leguminosae*, family name of pea.

Common name: Pea-mosaic virus.

Hosts: *LEGUMINOSAE—Lathyrus odoratus* L., sweet pea; *Pisum sativum* L., pea; *Trifolium pratense* L., red clover; *Vicia faba* L., broad bean. Experiment-

ally, also *Cicer arietinum* L.; *Desmodium canadense* (L.) DC.; *Lathyrus sativus* L., grass pea; *Lupinus albus* L., white lupine; *L. angustifolius*, blue lupine; *L. densiflorus* Benth.; *L. hartwegii* Lindl.; *L. nanus* Dougl.; *Medicago arabica* Huds., spotted bur clover; *M. hispida* Gaertn., oothed bur clover; *Melilotus alba* Desr., white sweet clover; *M. indica* All., annual yellow sweet clover; *M. officinalis* (L.) Lam., yellow sweet clover; *Phaseolus acutifolius* Gray, tepary bean; *P. vulgaris* L., bean; *Trifolium agrarium* L.; *T. carolinianum* Michx.; *T. dubium* Sibth.; *T. glomeratum* L., cluster clover; *T. hybridum* L., alsike clover; *T. incarnatum* L., crimson clover; *T. procumbens* L.; *T. reflexum* L.; *T. suaveolens*, Persian clover; *Vicia sativa* L., common vetch.

Insusceptible species: All tested species in families other than the *Leguminosae*.

Geographical distribution: United States, British Isles, Europe, New Zealand.

Induced disease: In pea, clearing of veins in young leaves, followed by chlorosis of newly formed leaves, stunting of plant, and systemic chlorotic mottling. In sweet pea, systemic chlorosis and chlorotic mottling, flower colors broken. In lupine, necrotic streak on one side of stem, stunting of plant and bending of growing point to injured side. Plant soon wilts and dies. In *Vicia faba*, mottled leaves contain characteristic isometric crystals in host-cell nuclei (especially within nucleoli) as well as in cell cytoplasm.

Transmission: By inoculation of expressed juice, with ease. By aphids, *Macrosiphum pisi* Kalt., *M. solanifolii* Ashm. (= *M. gei* Koch), and *Aphis rumicis* Linn. (*APHIDIDAE*). Not transmitted through seed.

Serological relationships: Specific precipitin reactions differentiate this virus from tobacco-mosaic virus, tobacco-etch virus, potato-mottle virus, potato mild-mosaic virus, potato aucuba-mosaic virus, and tobacco-ringspot virus.

Thermal inactivation: At 60° C in 10 minutes.

Literature: Chester, Phytopath., *25*, 1935, 686–701; Doolittle and Jones, *ibid.*, *15*, 1925, 763–772; Johnson and Jones, Jour. Agr. Res., *54*, 1937, 629–638; McWhorter, Phytopath., *31*, 1941, 760–761; Murphy and Pierce, *ibid.*, *27*, 1937, 710–721; Osborn, *ibid.*, *27*, 1937, 589–603; Pierce, Jour. Agr. Res., *51*, 1935, 1017–1039; Spierenburg, Tijdschr. Plantenz., *42*, 1936, 71–76; Zaumeyer and Wade, Jour. Agr. Res., *53*, 1936, 161–185.

20. **Marmor pisi** H. (*loc. cit.*, 90). From Latin *pisum*, pea.

Common name: Pea enation-mosaic virus.

Hosts: *LEGUMINOSAE—Pisum sativum* L., pea; *Vicia faba* L., broad bean. Experimentally, also *Lathyrus odoratus* L., sweet pea; *Soja max* (L.) Piper, soy bean; *Trifolium incarnatum* L., crimson clover.

Insusceptible species: *LEGUMINOSAE—Arachis hypogaea* L., peanut; *Medicago sativa* L., alfalfa; *Melilotus alba* Desr., white sweet clover; *M. officinalis* (L.) Lam., yellow sweet clover; *Phaseolus aureus* Roxb., mung bean; *P. vulgaris* L., bean; *Trifolium hybridum* L., alsike clover; *T. pratense* L., red clover; *T. repens* L., white Dutch clover. *SOLANACEAE—Lycopersicon esculentum* Mill., tomato; *Solanum tuberosum* L., potato.

Geographical distribution: United States, perhaps Germany.

Induced disease: In peas, systemic chlorotic mottling; in some varieties, as Alderman, occasional necrotic spots and numerous enations on lower surfaces of leaves. Pods distorted. In broad bean, systemic chlorotic spotting and striping of leaves. In sweet pea and soy bean, experimentally, systemic chlorotic mottling.

Transmission: By inoculation of expressed juice, using carborundum; more readily from aphid-inoculated plants than from mechanically-inoculated plants.

Infective in dilutions to 10^{-3}. By aphids, *Macrosiphum pisi* Kalt. and *M. solanifolii* Ashm. (= *M. gei* Koch) (*APHIDIDAE*), with incubation periods of about 12 hours before the insects can infect. Not through seeds from diseased plants.

Thermal inactivation: At 66° C in 10 minutes.

Literature: Böning, Forsch. Geb. Pflanzenkr. u. Immun. Pflanzenreich, *4*, 1927, 43–111; Johnson and Jones, Jour. Agr. Res., *54*, 1937, 629–638; Loring et al., Proc. Soc. Exp. Biol. and Med., *38*, 1938, 239–241; Osborn, Phytopath., *25*, 1935, 160–177; *28*, 1938, 749–754, 923–934; Pierce, Jour. Agr. Res., *51*, 1935, 1017–1039; Snyder, Phytopath., *24*, 1934, 78–80; Stubbs, *ibid.*, *27*, 1937, 242–266.

21. **Marmor medicaginis** H. (*loc. cit.*, 91). From New Latin *Medicago*, generic name of alfalfa (lucerne).

Common name: Alfalfa-mosaic virus.

Hosts: *LEGUMINOSAE—Medicago sativa* L., alfalfa (lucerne). *SOLANACEAE—Solanum tuberosum* L., potato. Experimentally, also transmissible to many species of dicotyledonous plants (summarized by Price, Am. Jour. Bot., *27*, 1940, 530–541) including *CUCURBITACEAE—Cucumis sativus* L., cucumber. *COMPOSITAE—Zinnia elegans* Jacq., zinnia. *LEGUMINOSAE—Phaseolus vulgaris* L., bean; *Trifolium incarnatum* L., crimson clover. *SOLANACEAE—Capsicum frutescens* L., pepper; *Lycopersicon esculentum* Mill., tomato; *Nicotiana tabacum* L., tobacco.

Geographical distribution: United States.

Induced disease: In alfalfa, systemic chlorotic mottling, tending to be masked at times. In bean, (most varieties) small necrotic primary lesions, reddish brown at periphery. No secondary lesions. Some bean varieties show no lesions after inoculation; one of these, Refugee Rogue, possesses two dominant genes either of which will confer this type of resistance. In tobacco, white necrotic flecks, small rings and arcs on inoculated leaves; later, systemic mottling, followed by production of necrotic oak-leaf patterns; virus content may be low in plants long diseased, especially in summer.

Transmission: By inoculation of expressed juice. By aphids, *Macrosiphum pisi* Kalt. (for typical strain) and *M. solanifolii* Ashm. (for potato-calico strain) (*APHIDIDAE*). Not through seeds from diseased plants.

Immunological relationships: Resistance to superinfection with the type of this virus is conferred by earlier infection with potato-calico virus (now considered a related strain but earlier regarded as distinct), but not by earlier infection with potato-mottle virus, cucumber-mosaic virus, or the Canada-streak strain of potato aucuba-mosaic virus.

Thermal inactivation: At 65 to 70° C in 10 minutes.

Other properties: Sedimentation constant, $73.9 \pm 5.2 \times 10^{-13}$ cm. per sec. in a unit centrifugal field. Specific volume 0.673. Particles spherical or nearly so. Diameter 16.5 millimicrons; weight 2.1×10^{6} times hydrogen unit. Isoelectric point about pH 4.6. Inactivated and, more slowly, hydrolyzed by trypsin.

Literature: Black and Price, Phytopath., *30*, 1940, 444–447; Lauffer and Ross, Jour. Am. Chem. Soc., *62*, 1940, 3296–3300, Pierce, Phytopath., *24*, 1934, 87–115; Price, Am. Jour. Bot., *27*, 1940, 530–541; Ross, Phytopath., *31*, 1941, 394–410, 410–420; Wade and Zaumeyer, Jour. Am. Soc. Agron., *32*, 1940, 127–134; Zaumeyer, Jour. Agr. Res., *56*, 1938, 747–772.

Strains: At least one strain of alfalfa-mosaic virus was formerly considered as an independent virus, causing a disease known as calico in potato. It has now been given varietal rank and distinguished from the type, var. *typicum* Black and Price (Phytopath., *30*, 1940, 446) by the following name:

21a. *Marmor medicaginis* var. *solani* Black and Price (Phytopath., *30*, 1940,

446). From New Latin *Solanum*, generic name of potato.

Common name: Potato-calico strain of alfalfa-mosaic virus. Differing from the type by inducing a more severe disease in potato, in which it is commonly found in nature. (Price and Black, Phytopath., *30*, 1940, 444–447; Dykstra, *ibid.*, *29*, 1939, 917–933; Porter, Potato Assoc. Amer. Proc., *18*, 1931, 65–69; Hilgardia, *6*, 1931, 277–294; *9*, 1935, 383–394.)

22. **Marmor tulipae** H. (*loc. cit.*, 52). From New Latin *Tulipa*, generic name of tulip.

Common name: Tulip color-adding virus.

Hosts: *LILIACEAE—Tulipa gesneriana* L., garden tulip; *T. eichleri* Regel; *T. greigi* Regel.

Insusceptible species: *AMARYLLIDACEAE—Narcissus* sp., narcissus. *IRIDACEAE—Iris germanica* L., iris. *LILIACEAE—Allium cepa* L., onion. *SOLANACEAE—Nicotiana tabacum* L., tobacco.

Geographical distribution: Wherever hybrid tulips are grown.

Induced disease: In tulip, no obvious effect on leaves but dark striping of flower by pigment intensification. Little interference with growth of plant. No intracellular bodies.

Transmission: By hypodermic injections of expressed juice in dilutions to 10^{-6}. By aphids, *Myzus persicae* (Sulz.), *Macrosiphum solanifolii* Ashm. (= *M. gei* Koch, *Illinoia solanifolii* Ashm.), *Aphis* (= *Anuraphis*) *tulipae* B. de Fonsc. (on bulbs), and perhaps *Macrosiphum pelargonii* Kalt. (*APHIDIDAE*). Not through seeds from diseased plants.

Thermal inactivation: At 65 to 70° C in 10 minutes.

Literature: Hughes, Ann. Appl. Biol., *18*, 1931, 16–29; *21*, 1934, 112–119; McWhorter, Phytopath., *22*, 1932, 998 (Abst.); *25*, 1935, 898 (Abst.); Ann. Appl. Biol., *25*, 1938, 254–270.

23. **Marmor mite** H. (*loc. cit.*, 53). From Latin *mitis*, mild.

Common name: Lily latent-mosaic virus.

Hosts: *LILIACEAE—Lilium amabile; L. auratum* Lindl.; *L. canadense* L.; *L. candidum* L.; *L. cernuum; L. chalcedonicum* L.; *L. croceum* Chaix.; *L. davmottiae; L. elegans* Thunb.; *L. formosanum* Stapf.; *L. giganteum; L. henryi* Baker; *L. leucanthum; L. longiflorum* Thunb.; *L. myriophyllum; L. pumilum; L. regale* Wils.; *L. sargentiae* Wils.; *L. speciosum* Thunb.; *L. superbum* L.; *L. testaceum* Lindl.; *L. tigrinum* Ker; *L. umbellatum* Hort.; *L. wallacei; Tulipa gesneriana* L., garden tulip; *T. clusiana* Vent.; *T. linifolia* Regel.

Insusceptible species: *LILIACEAE—Allium cepa* L., onion; *Lilium hansoni* Leichtl. *IRIDACEAE—Iris germanica* L., iris. *SOLANACEAE—Nicotiana tabacum* L., tobacco.

Geographical distribution: Wherever lilies and tulips are cultivated.

Induced disease: In Easter lily, masked symptoms or systemic chlorotic mottling, in either case without necrotic flecking. In tulip, systemic chlorotic mottling in foliage and flower "breaking" (color removal, except in a few varieties in which color intensification occurs instead). Intracellular bodies characterize invaded tissues.

Transmission: By inoculation of expressed juice (rubbing surface of leaves), in both lily and tulip. By plugging and grafting of dormant bulbs of tulip. By aphids, *Myzus persicae* (Sulz.), *Macrosiphum solanifolii* Ashm. (= *M. gei* Koch), and *Aphis* (= *Anuraphis*) *tulipae* B. de Fonsc. (*APHIDIDAE*). Not through seeds from mosaic *Lilium longiflorum*.

Thermal inactivation: At 65 to 70° C in 10 minutes.

Literature: Atanasoff, Bull. Soc. Bot. Bulgarie, *2*, 1928, 51–60; Brierley, Phytopath., *29*, 1939, 3 (Abst.); *30*, 1940, 250–

257; *31*, 1941, 838–843; Brierley and Doolittle, *ibid.*, *30*, 1940, 171–174; Cayley, Ann. Appl. Biol., *15*, 1928, 529–539; *19*, 1932, 153–172; Guterman, Hort. Soc. N. Y., Yearbk., *1930*, 51–102; Hall, Gard. Chron., *93*, 1933, 330–331; Hughes, Ann. Appl. Biol,. *21*, 1934, 112–119; McKay and Warner, Nat. Hort. Mag., *12*, 1933, 179–216; McWhorter, Phytopath., *25*, 1935, 898 (Abst.); Science, *86*, 1937, 179; Ann. Appl. Biol., *25*, 1938, 254–270; Science, *88*, 1938, 411; Ogilvie and Guterman, Phytopath., *19*, 1929, 311–315.

24. **Marmor iridis** H. (*loc. cit.*, 55). From New Latin *Iris*, generic name of iris.

Common name: Iris-mosaic virus.

Hosts: *IRIDACEAE—Iris filifolia* Boiss., *I. tingitana* Boiss. and Reut., and *I. xiphium* L., bulbous irises; *Iris ricardi* Hort.; *I. unguicularis* Poir.; bearded iris, variety William Mohr.

Insusceptible species: *SOLANACEAE—Lycopersicon esculentum* Mill., tomato; *Nicotiana tabacum* L., tobacco; *Petunia hybrida* Vilm., petunia. *LILIACEAE—Tulipa gesneriana* L., tulip.

Geographical distribution: United States (Washington, Oregon, California), Holland, Bulgaria, France, England.

Induced disease: In bulbous irises, dwarfing of plant, chlorotic mottling of foliage, breaking of flowers. Rate of increase in planting stock decreased. Flower breaks usually darker than normal color of flower. Vacuolate intracellular bodies in some affected tissues.

Transmission: By injection of freshly extracted juice of diseased plants into internodal tissue. By aphids, *Macrosiphum* (= *Illinoia*) *solanifolii* Ashm. and *Myzus persicae* (Sulz.) (*APHIDIDAE*).

Literature: Brierley and McWhorter, Jour. Agr. Res., *53*, 1936, 621–635.

25. **Marmor sacchari** H. (*loc. cit.*, 60). From New Latin *Saccharum*, generic name of sugar cane, from Latin *saccharum*, sugar.

Common name: Sugar-cane mosaic virus.

Hosts: *GRAMINEAE—Saccharum officinarum* L., sugar cane; *Holcus sorghum* L., sorghum; *H. sudanensis* Bailey, Sudan grass; *Brachiaria platyphylla* Nash; *Chaetochloa magna* Scribn.; *C. verticillata* Scribn.; *Paspalum boscianum* Fluegge; *Syntherisma sanguinale* Dulac. Experimentally, also *Zea mays* L., corn (maize); *Chaetochloa lutescens* Stuntz; *Echinochloa crusgalli* Beauv.; *Miscanthus sinensis* Anderss., eulalia; *Panicum dichotomiflorum* Michx.; *Pennisetum glaucum* R. Br., pearl millet; *Saccharum narenga* Wall.

Insusceptible species: All tested species other than *Gramineae*.

Geographical distribution: Originally in Far East; now in nearly all countries where sugar cane is grown; believed still to be absent from Mauritius.

Induced disease: In sugar cane, systemic mottling chlorosis, light areas of pattern elongated, but crossing veins. Occasionally, stem cankers. Regularly, discoloration and necrosis in mature inner stalk tissues. Vacuolate intracellular bodies occur in diseased tissues. Canes sometimes recover, spontaneously losing the virus and becoming susceptible to reinfection.

Transmission: By inoculation of expressed juice (puncture through inoculum into young leaf). By aphids, *Aphis maidis* Fitch, *Carolinaia cyperi* Ainslie, *Hysteroneura setariae* (Thomas), and *Toxoptera graminum* Rond.; not by *Sipha flava* Forbes (*APHIDIDAE*). Not by *Draeculacephala mollipes* (Say) (*CICADELLIDAE*).

Serological relationships: Specific neutralizing and precipitating antibodies have been demonstrated.

Thermal inactivation: At 53 to 54° C in 10 minutes in leaf tissues.

Other properties: Active after storage 27 days at −6° C.

Literature: Brandes, Jour. Agr. Res., *19*, 1920, 131–138, 517–522; *24*, 1923, 247–262; Desai, Current Science, *3*, 1935, 18; Forbes and Mills, Phytopath., *33*, 1943, 713–718; Ingram and Summers, Jour. Agr. Res., *52*, 1936, 879–888; Kunkel, Bull. Exp. Sta. Hawaiian Sugar Planters' Assoc., Bot. Ser., *3*, 1924, 115–167; Matz, Jour. Agr. Res., *46*, 1933, 821–839; Rafay, Indian Jour. Agr. Science *5*, 1935, 663–670; Scín, Jour. Dept. Agr. Porto Rico, *14*, 1930, 49–68; Stoneberg, U. S. Dept. Agr., Tech. Bull. 10, 1927; Tate and Vandenberg, Jour. Agr. Res., *59*, 1939, 73–79.

26. **Marmor cepae** H. (*loc. cit.*, 66). From Latin *cepa*, onion.

Common name: Onion yellow-dwarf virus.

Host: *LILIACEAE—Allium cepa* L., onion (the variety *viviparum* Metz. is symptomless when infected and may serve as an unrecognized reservoir of virus).

Geographical distribution: United States, Germany, Czecho-Slovakia, Russia, New Zealand.

Induced disease: In onion (most varieties), yellow streaks at base of developing leaf, followed by yellowing, crinkling, and flattening of newly formed leaves; leaves prostrate, flower stalks bent, twisted, stunted; plants reduced in size, bulbs small, yield of seeds reduced. A few varieties of onion are relatively tolerant, and the tree-onion, var. *viviparum* is symptomless after infection.

Transmission: By inoculation of expressed juice. By 48 of 51 tested species of aphid, principally *Aphis rumicis* Linn., *A. maidis* Fitch, and *Rhopalosiphum prunifoliae* Fitch (*APHIDIDAE*). Not through seeds from diseased plants. Not by contaminated soil.

Thermal inactivation: At 75 to 80° C in 10 minutes.

Other properties: Virus withstands dilution to 10^{-4}, storage at 29° C for about 100 hours and storage at −14° C for more than time tested (6 hours), but is inactivated by drying in leaf tissues.

Literature: Andreyeff, Rev. Appl. Mycol., *17*, 1938, 575–576; Blattny, Ochrana Rostlin, *10*, 1930, 130–138; Bremer, Phytopath. Ztschr., *10*, 1937, 79–105; Brierley and Smith, Phytopath., *34*, 1944, 506–507; Chamberlain and Baylis, New Zealand Jour. Science and Technology, *21*, 1939, 229A–236A; Drake et al., Iowa State Coll. Jour. Science, *6*, 1932, 347–355; Jour. Econ. Ent., *26*, 1933, 841–846; Henderson, Phytopath., *20*, 1930, 115 (Abst.); Iowa State Coll., Research Bull. *188*, 1935, 211–255; Melhus et al., Phytopath., *19*, 1929, 73–77; Porter, U. S. Dept. Agr., Plant Dis. Rept., *12*, 1928, 93; Tate, Iowa State Coll. Jour. Science, *14*, 1940, 267–294.

27. **Marmor scillearum** Smith and Brierley (Phytopath., *34*, 1944, 503.) From New Latin *Scilleae*, name of tribe in which hosts are classed.

Common name: Ornithogalum-mosaic virus.

Hosts: *LILIACEAE* (of the tribe Scilleae)—*Ornithogalum thyrsoides* Jacq.; probably also *Galtonia candicans* Decne.; *Hyacinthus orientalis* L., hyacinth; *Lachenalia* sp.

Insusceptible species: *LILIACEAE* (of the tribe Scilleae)—*Muscari botryoides* Mill.; *Scilla peruviana* L.; *Camassia leichtlinii* (Baker) S. Wats.; *Hyacinthus azureus* (Fenzl.) Baker. *AMARYLLIDACEAE—Pancratium maritimum; Zephyranthus* sp. *IRIDACEAE—Tritonia crocata* (L.) Ker. *LILIACEAE—Agapanthus africanus; Allium cepa*, onion; *A. cernuum* Roth.; *A. fistulosum* L.; *A. porrum* L.; *Gloriosa rothschildiana* O'Brien; *Lilium formosanum* Stapf.; and *L. longiflorum*. *SOLANACEAE—Nicotiana tabacum* L.

Geographical distribution: United States (Oregon; probably also Alabama and presumed to be widespread in plants of the squill tribe, *Scilleae*, of the family *LILIACEAE*).

Induced disease: In *Ornithogalum thyrsoides*, young leaves finely mottled with light and dark green, and becoming more conspicuously mottled with gray or yellow as the leaves mature; flower stalks sometimes boldly marked with light and dark green blotches. In perianth segments, thin longitudinal streaks.

Transmission: By inoculation of expressed juice in the presence of fine carborundum powder, with difficulty. By aphids, *Aphis gossypii* Glov., *Macrosiphum lilii* Monell, *M. solanifolii* Ashm., and *Myzus persicae* (Sulz.); less efficiently by *Myzus circumflexus* (Buckt.) (*APHIDIDAE*).

Key to the species of the Miscellaneous Mosaic-Virus Group.

Many of the following viruses, although described in some detail in the literature, stand in need of reinvestigation to determine additional properties and possible relationships to preceding groups.

I. Affecting species of *MALVACEAE*.
- 28. *Marmor abutilon.*

II. Affecting species of *CELASTRACEAE*.
- 29. *Marmor euonymi.*

III. Affecting species of *OLEACEAE*.
- 30. *Marmor ligustri.*

IV. Affecting species of *LEGUMINOSAE* (and no. 39, other families also).
- 31. *Marmor laburni.*
- 32. *Marmor arachidis.*
- 33. *Marmor trifolii.*
- 34. *Marmor pachyrhizi.*
- 35. *Marmor vignae.*
- 36. *Marmor repens.*
- 37. *Marmor fastidiens.*
- 38. *Marmor iners.*
- 39. *Marmor efficiens.*

V. Affecting species of *GRAMINEAE*.
- 40. *Marmor tritici.*
- 41. *Marmor graminis.*

VI. Affecting species of *MUSACEAE*.
- 42. *Marmor abaca.*

VII. Affecting species of *PASSIFLORACEAE*.
- 43. *Marmor passiflorae.*

VIII. Affecting species of *ROSACEAE*.
- 44. *Marmor flaccumfaciens.*
- 45. *Marmor rosae.*
- 46. *Marmor veneniferum.*
- 47. *Marmor mali.*
- 48. *Marmor fragariae.*
- 49. *Marmor marginans.*
- 50. *Marmor rubi.*
- 51. *Marmor persicae.*
- 52. *Marmor astri.*
- 53. *Marmor rubiginosum.*
- 54. *Marmor cerasi.*
- 55. *Marmor lineopictum.*
- 56. *Marmor pallidolimbatus.*
- 57. *Marmor nerviclarens.*

IX. Affecting species of *VITACEAE*.

58. *Marmor viticola.*

X. Affecting species of *SANTALACEAE*.

59. *Marmor santali.*

XI. Affecting species of *CONVOLVULACEAE* and, experimentally, of other families.

60. *Marmor secretum.*

XII. Affecting species of *GERANIACEAE*.

61. *Marmor pelargonii.*

XIII. Affecting species of *SOLANACEAE* and in most cases also of other families.

62. *Marmor angliae.*

63. *Marmor aevi.*

64. *Marmor raphani.*

XIV. Affecting species of *PRIMULACEAE*.

65. *Marmor primulae.*

XV. Affecting species of *MORACEAE*.

66. *Marmor caricae.*

XVI. Affecting species of *RUTACEAE*.

67. *Marmor italicum.*

28. **Marmor abutilon** H. (*loc. cit.*, 50). From New Latin *Abutilon*, generic name of a host.

Common name: Abutilon-mosaic virus.

Hosts: *MALVACEAE—Abutilon striatum* Dicks. var. *thompsonii* Veitch. Experimentally, also *Abutilon arboreum* Sweet; *A. avicennae* Gaertn.; *A. esculentum* St. Hil.; *A. indicum* Sweet; *A. insigne* Planch.; *A. megapotamicum* St. Hil. and Naud.; *A. regnellii* Miq.; *A. sellowianum* Regel; *A. venosum* Lem.; *A. vitifolium* Presl.; *Althaea ficifolia* Cav.; *A. officinalis* L.; *A. rosea* Cav.; *Anoda hastata* Cav.; *Kitaibelia vitifolia* Willd.; *Malva borealis; M. crispa; M. mauritiana* Mill.; *M. sylvestris* L.; *M. verticillata* L.; *Malvastrum capense* Garcke; *Modiola decumbens* G. Don.; *Sida mollis* Herb.; *S. napaea* Cav.; *Sidalcea candida* A. Gray.

Insusceptible species: *MALVACEAE—Althaea taurinensis; Sidalcea purpurea; Sphaeralcea umbellata* G. Don.

Geographical distribution: Germany, France, England, United States; originally obtained from a single variegated seedling found among green plants of *Abutilon striatum* imported from the West Indies in 1868 by Veitch and Sons; subsequently the infected plant [illegible] propagated vegetatively as an ornamental variety.

Induced disease: In *Abutilon*, systemic chlorotic mottling. Recovery occurs if there is persistent removal of affected leaves, suggesting that the virus does not increase in stems. After recovery, plants are susceptible to reinfection.

Transmission: By grafting, except patch-bark-grafting, which is ineffective. Occasionally through seeds from diseased plants. Not by inoculation of expressed juice. No insect vector is known.

Varieties: Distinctive strains have been noted, but not separately named; one isolate originally occurring in *Abutilon darwini* var. *tesselatum*, seems to belong here; it differs from the type principally in severity of induced disease and in ability to infect *Lavatera arborea*.

Literature: Baur, Ber. d. Deutsch. Bot. Gesellsch., *22*, 1904, 453–460; *24*, 1906, 416–428; *25*, 1907, 410–413; K. Preuss. Akad. Wiss., Sitzungsber., 1906, 11–19; Davis, Ann. Missouri Bot. Gard., *16*, 1929, 145–226; Hertzsch, Ztschr. f. Bot., *20*, 1927, 65–85; Keur, Phytopath., *23*, 1933, 20 (Abst.); *24*, 1934, 12–13 (Abst.); Bull. Torrey Bot. Club, *61*, 1934, 53–70; Lindemuth, Gartenflora, *51*, 1902, 323–

29. **Marmor euonymi** H. (*loc. cit.*, 51). From New Latin *Euonymus*, generic name of host.

Common name: Euonymus-mosaic virus.

Hosts: *CELASTRACEAE—Euonymus japonica* L. f. (sometimes written *Evonymus japonicus*). Probably also *E. radicans* Sieb.

Geographical distribution: Germany.

Induced disease: In *Euonymus japonica*, persistent yellowing along veins.

Transmission: By grafting.

Literature: Baur, Ber. d. Deutsch. Bot. Gesellsch., *26a*, 1908, 711-713; Rischkow, Biol. Zentralbl., *47*, 1927, 752-764.

30. **Marmor ligustri** H. (*loc. cit.*, 52). From New Latin *Ligustrum*, generic name of host, from Latin *ligustrum*, ancient name of privet plant.

Common name: Ligustrum-mosaic virus.

Host: *OLEACEAE—Ligustrum vulgare* L., common privet.

Geographical distribution: Germany.

Induced disease: Systemic chlorotic spotting.

Transmission: By grafting. Not through seeds from diseased plants.

Literature: Baur, Ber. d. Deutsch. Bot. Gesellsch., *25*, 1907, 410-413.

31. **Marmor laburni** H. (*loc. cit.*, 51). From generic name of a host plant, *Laburnum vulgare*.

Common name: Laburnum-mosaic virus.

Hosts: *LEGUMINOSAE—Laburnum vulgare Griseb.* (= *L. anagyroides* Medic.), bean tree. Experimentally, also *Cytisus hirsutus* L.

Insusceptible species: *LEGUMINOSAE—Laburnum alpinum* Griseb.; *Cytisus purpureus*.

Geographical distribution: Germany.

Induced disease: Systemic chlorotic variegation.

Transmission: By bark grafts or by budding. Not through seeds from diseased plants of *Laburnum vulgare*.

Literature: Baur, Ber. d. Deutsch. Bot. Gesellsch., *25*, 1907, 410-413.

32. **Marmor arachidis** H. (*loc. cit.*, 67). From New Latin *Arachis*, generic name of peanut.

Common name: Peanut-rosette virus.

Host: *LEGUMINOSAE—Arachis hypogaea* L., peanut.

Geographical distribution: Union of South Africa, Madagascar, Tanganyika Territory, Uganda, Senegal, Gambia, Sierra Leone, Java.

Induced disease: In peanut, yellowing of young leaves, at first with green veins; reduction in leaf size, petiole length, and internode length, producing rosette; curling and distortion of later-formed, wholly chlorotic or chlorotically mottled leaflets. Seed formation inhibited. No abnormal proliferation of tissues.

Transmission: By grafting. By both winged and wingless individuals of the aphid, *Aphis laburni* Kalt. (= *A. leguminosae* Theob.) (*APHIDIDAE*). Not by 13 tested species of leafhoppers. Not by inoculation of expressed juice. Not through seed from diseased plants. Not through soil.

Literature: Hayes, Trop. Agr., *9*, 1932, 211-217; McClintock, Science, *45*, 1917, 47-48; Soyer, Publ. Inst. Nat. Étud. Agron. Congo Belge, Sér. Sci., *21*, 1939, 23 pages (Rev. Appl. Mycol., *19*, 1940, 386, Abst.); Storey and Bottomley, Ann. Appl. Biol., *15*, 1928, 26-45; Zimmerman, Der Pflanzer, *3*, 1907, 129-133; *9*, 1913, 59-63.

33. **Marmor trifolii** H. (*loc. cit.*, 93). From New Latin *Trifolium*, generic name of red clover, from Latin *trifolium*, clover.

Common name: Red-clover vein-mosaic virus.

Hosts: *LEGUMINOSAE—Trifolium pratense* L., red clover; *Lathyrus odoratus* L., sweet pea; *Vicia faba* L., broad bean. Experimentally, also *Trifolium hybridum* L., alsike clover; *T. incarnatum* L., crim-

son clover; *T. repens* L., white clover; *Melilotus alba* Desr., white sweet clover; *Pisum sativum* L., pea.

Insusceptible species: *LEGUMINOSAE—Phaseolus vulgaris* L., bean; *P. aureus* Roxb., mung bean; *Medicago sativa* L., alfalfa. *SOLANACEAE—Lycopersicon esculentum* Mill., tomato; *Nicotiana tabacum* L., tobacco; *N. glutinosa* L.; *N. langsdorffii* Weinm.; *N. rustica* L.; *N. sylvestris* Spegaz. and Comes; *Solanum tuberosum* L., potato.

Geographical distribution: United States.

Induced disease: In red clover, yellow color along veins, but no mottling. Sometimes small yellow spots in interveinal areas. Little or no stunting. In *Vicia faba*, experimentally, necrotic splotches or rings sometimes at site of inoculation. Clearing of veins followed by appearance of whitish bands along the veins. Stalks discolored, purplish. Diseased plants are stunted and often die back to a point near the base of the stalk, inducing new growth from buds on the stem.

Transmission: By inoculation of expressed juice, using carborundum. By aphid, *Macrosiphum pisi* Kalt. (*APHIDIDAE*), without incubation period and without long retention. Not by aphids, *Macrosiphum solanifolii* Ashm. (= *M. gei* Koch) or *Aphis rumicis* Linn. (*APHIDIDAE*).

Thermal inactivation: At 60° C in 10 minutes.

Literature: Osborn, Phytopath., *27*, 1937, 1051–1058; Zaumeyer, Jour. Agr. Res., *56*, 1938; 747–772; Zaumeyer and Wade, Phytopath., *27*, 1937, 1009–1013.

34. **Marmor pachyrhizi** *spec. nov.* From New Latin *Pachyrhizus*, generic name of sincamas.

Common name: Sincamas-mosaic virus.

Host: *LEGUMINOSAE—Pachyrhizus erosus* (L.) Urb., sincamas (yam bean).

Insusceptible species: *LEGUMINOSAE—Phaseolus vulgaris* L., bean.

Geographical distribution: Philippine Islands.

Induced disease: In sincamas, chlorotic mottling of foliage; in plants infected when young, dwarfing.

Transmission: By inoculation of expressed juice, in the presence of sand as abrasive. Through about 25 percent of the seeds from infected plants. Not through soil, interlacing of roots, or casual contacts of leaves and stems. No insect vector is known.

Literature: Fajardo and Marañon, Philippine Jour. Science, *48*, 1932, 129–142.

35. **Marmor vignae** *spec. nov.* From New Latin *Vigna*, generic name of cowpea, from family name of an Italian botanist, Domenico Vigna.

Common name: Cowpea-mosaic virus.

Hosts: *LEGUMINOSAE—Vigna sinensis* (L.) Endl., cowpea. Experimentally, also *Phaseolus lunatus* L., lima bean.

Geographical distribution: United States (Arkansas, Oklahoma, Louisiana, Indiana, Georgia, Iowa, Mississippi, Kansas, New Jersey).

Induced disease: In cowpea, clearing of veins followed by chlorotic mottling, slight convex cupping of leaflets, shortened internodes, abortion of flowers, twisting of petioles, delayed maturity. Malformation of leaves, stunting of plants, and reduction of yield more pronounced in some varieties of cowpea than in others.

Transmission: By inoculation of expressed juice, especially in the presence of fine carborundum powder. By aphids, *Macrosiphum solanifolii* Ashm., *M. pisi* Kalt., *Aphis gossypii* Glov. (*APHIDIDAE*); not by various beetles nor by the bean leafhopper, *Empoasca fabae* LeB. (*CICADELLIDAE*). Through 5 per cent of seeds from infected cowpea plants.

Thermal inactivation: At 72 to 75° C in 10 minutes.

Other properties: Infectious in dilutions as high as 1:1000 and after 2 days

storage in expressed juice at room temperature, 20 to 25° C.

Literature: Elliott, Phytopath., *11*, 1921, 146–148; Gardner, Indiana Acad. Science Proc., *36*, 1927, 231–247; *37*, 1928, 417; McLean, Phytopath., *31*, 1941, 420–430; Smith, Science, *60*, 1924, 268.

36. **Marmor repens** Johnson. (Phytopath., *32*, 1942, 114.) From Latin *repens*, unlooked for, in reference to unexpected discovery of this virus as a constituent of a complex formerly regarded as a single virus, so-called "white-clover mosaic virus".

Common name: Pea-wilt virus.

Hosts: *LEGUMINOSAE—Trifolium repens* L., white clover. Experimentally, also *Lathyrus odoratus* L., *Lens esculenta* Moench.; *Lupinus albus* L.; *Medicago lupulina* L.; *Melilotus alba* Desr.; *Phaseolus aureus* Roxb., mung bean; *P. vulgaris* L., bean; *Pisum sativum* L., pea; *Trifolium hybridum* L.; *T. incarnatum* L.; *T. pratense* L.; *Vicia faba* L.; *V. sativa* L.; *Vigna sinensis* (L.) Endl., cowpea.

Insusceptible species: *CARYOPHYLLACEAE—Stellaria media* (L.) Cyrill. *CHENOPODIACEAE—Beta vulgaris* L.; *Spinacia oleracea* L. *COMPOSITAE—Callistephus chinensis* Nees; *Lactuca sativa* L.; *Taraxacum officinale* Weber; *Zinnia elegans* Jacq. *CRUCIFERAE—Barbarea vulgaris* R. Br.; *Brassica oleracea* L.; *Raphanus sativus* L. *CUCURBITACEAE—Cucumis sativus* L. *GRAMINEAE—Zea mays* L. *LEGUMINOSAE—Glycine max* Merr.; *Lupinus hirsutus* L.; *Medicago sativa* L. *LILIACEAE—Lilium formosanum* Stapf. *PLANTAGINACEAE—Plantago lanceolata* L.; *P. major* L. *POLYGONACEAE—Rumex acetosella* L. *SCROPHULARIACEAE — Antirrhinum majus* L. *SOLANACEAE—Datura stramonium* L.; *Lycopersicon esculentum* Mill.; *Nicotiana glutinosa* L.; *N. rustica* L.; *N. sylvestris* Spegaz. and Comes; *N. tabacum* L.; *Solanum nigrum* L.

Geographical distribution: United States (Washington).

Induced disease: In white clover, systemic chlorotic mottling. In pea, experimentally, originally infected leaves wilt and die, remaining attached to the stem by their shriveled petioles; a few adjacent lower leaves may also wilt and die; in most varieties the top foliage remains green, but in two varieties, Alaska and Canada White, it mottles faintly; stems show faint grayish discoloration; plants are retarded in growth and dwarfed. If pea-mottle virus, *Marmor efficiens* Johnson, is also present, a severe streak disease occurs. Intracellular inclusions absent. In mung bean, experimentally, necrotic zonate local lesions. In cowpea, experimentally, brown necrotic local lesions in inoculated primary leaves, diffuse areas of bleaching in uninoculated trifoliate leaves. In bean, experimentally, mild chlorotic mottling except in three varieties that appear insusceptible (varieties Ideal Market, Kentucky Wonder, and Navy Robust).

Transmission: By inoculation of expressed juice. Not by dodder, *Cuscuta campestris* Yunck. (*CONVOLVULACEAE*). Not by pea aphid, *Macrosiphum pisi* Kalt. (*APHIDIDAE*). No insect vector is known.

Thermal inactivation: At 58 to 60° C in 10 minutes.

Filterability: Passes Berkefeld W filter candle.

Other properties: Infectious in dilution of 1:100,000. Not inactivated by storage in juice of infected plants at about 25° C for one month or by similar storage in dried tissues of infected pea plants.

Literature: Johnson, Phytopath., *32*, 1942, 103–116; Pierce, Jour. Agr. Res., *51*, 1935, 1017–1039.

37. **Marmor fastidiens** *spec. nov.* From Latin *fastidiens*, disdaining, in reference to slight irregularities in the reported host ranges of constituent strains and failure of this virus to infect certain varieties of the pea although it

may utilize many other varieties of this species as host.

Common name: Alsike-clover mosaic virus.

Hosts: *LEGUMINOSAE—Trifolium hybridum* L., alsike clover; *Pisum sativum* L., pea (except the varieties Horal, Perfection, and Surprise). Experimentally, also *Crotalaria striata* DC.; *C. retusa* L.; and *C. spectabilis* Roth (the two last-named species are reported to be insusceptible to the type strain of the virus, but susceptible to one or more of the other tested strains); *Lupinus albus* L.; *L. angustifolius* L.; *Medicago sativa* L.; *Melilotus alba* Desr.; *Phaseolus vulgaris* L., bean; *Trifolium incarnatum* L.; *T. pratense* L.; *Vicia faba* L.

Insusceptible species: *SOLANACEAE—Datura stramonium* L.; *Nicotiana glauca* Graham; *N. glutinosa* L.; *N. tabacum* L.; *Petunia hybrida* Vilm. *LEGUMINOSAE—Phaseolus aureus* Roxb., mung bean; *P. lunatus* L., sieva bean; *Soja max* (L.) Piper, soybean; *Trifolium repens* L., white clover; *Vicia sativa* L., spring vetch.

Induced disease: In pea and bean, experimentally, systemic chlorotic mottling; some isolates kill inoculated leaves and even cause death of infected plants.

Transmission: By inoculation with expressed juice, at dilutions to 1:6000 or 1:8000. No insect vector is known.

Thermal inactivation: At 60 to 65° C in 10 minutes; one strain at lower temperature, 54 to 58° C.

Strains: Several strains have been distinguished by the severity of their effects on host plants. These may be characterized as follows: var. *fastidiens, var. nov.*, type variety, the first of the strains to be described (originally known as alsike clover mosaic virus 1), induces mild disease in pea, does not infect red clover; var. *mite, var. nov.*, described as pea mosaic virus 4, induces mild symptoms on pea, infects red clover; var. *reprimens, var. nov.*, described as pea mosaic virus 5, stunts peas severely; var. *denudans, var. nov.*, described as alsike clover mosaic virus 2, defoliates pea plants. Varietal names from New Latin *fastidiens*, epithet of the species, and from Latin *mitis*, mild; *reprimere*, to restrain; and *denudare*, to denude; all three in reference to induced symptoms.

Literature: Wade and Zaumeyer, Phytopath., *28*, 1938, 505–511; Zaumeyer, Jour. Agr. Res., *60*, 1940, 433–452.

38. **Marmor iners** *spec. nov.* From Latin *iners*, sluggish or inert, in reference to failure of the virus to spread systemically in certain of its hosts.

Common name: Pea-streak virus.

Hosts: *LEGUMINOSAE—Pisum sativum* L., pea. Experimentally, also *Galega officinalis* L., goat's rue; *Glycine soja* Sieb. and Zucc., soya bean; *Lathyrus odoratus* L., sweet pea; *Lotus hispidus* Desf.; *Lupinus angustifolius* L., blue lupin; *L. luteus* L., yellow lupin; *L. mutabilis* Sweet; *Phaseolus vulgaris* L., bean; *Trifolium arvense* L., haresfoot trefoil; *T. cernuum* Brot., nodding clover; *T. fragiferum* L., strawberry clover; *T. glomeratum* L., cluster clover; *T. hybridum* L., alsike clover; *T. pratense* L., red clover; *T. repens* L., white clover; *Vicia villosa* Roth., hairy vetch. *CUCURBITACEAE—Cucumis melo* L., rock melon; *C. sativus* L., cucumber; *Cucurbita pepo* L., marrow.

Insusceptible species: *CHENOPODIACEAE—Spinacia oleracea* L., spinach; *Beta vulgaris* L., beet. *COMPOSITAE—Calendula officinalis* L., calendula; *Lactuca sativa* L., lettuce; *Zinnia elegans* Jacq., zinnia. *CRUCIFERAE—Brassica napus* L., swede; *B. oleracea* L., cabbage; *B. rapa* L., turnip; *Matthiola incana* R. Br., stock; *Raphanus sativus* L., radish; *Sisymbrium officinale* (L.) Scop., hedge mustard. *LEGUMINOSAE—Arachis hypogaea* L., peanut; *Lathyrus latifolius* L., perennial sweet pea; *L. pubescens* Hook. and Arn., Argentine sweet pea; *Lotus corniculatus* L.; *Lupinus arboreus* Sims, tree lupin; *Medicago arabica* Huds.; *M. sativa* L., lucerne (alfalfa); *Phaseolus multiflorus* Willd., run-

ner bean; *Trifolium striatum* L., striated clover; *T. subterraneum* L., subterranean clover; *Vicia faba* L., broad bean. *PLANTAGINACEAE* — *Plantago lanceolata* L., plantain. *SCROPHULARIACEAE*—*Antirrhinum majus* L. *SOLANACEAE*—*Cyphomandra betacea* Sendt., tree tomato; *Datura stramonium* L., Jimson weed; *Nicotiana glauca* R. Grah.; *N. rustica* L., Turkestan tobacco; *N. tabacum* L., tobacco; *Physalis peruviana* L., Cape gooseberry; *Solanum nigrum* L., black nightshade. *TROPAEOLACEAE*—*Tropaeolum majus* L., nasturtium. *UMBELLIFERAE*—*Apium graveolens* L., celery.

Geographical distribution: New Zealand.

Induced disease: In the pea, stunting, wilting of young leaves, purple or purple-brown spotting on young leaves, dark streak on stem. Near tip, stem may die. Stem becomes brittle, tip bent to one side. Pods may remain flat and turn dark purple or purple-brown, or if already formed may show purple or purple-brown markings. Older leaves turn yellow, then brown and shrivelled. Infected plants usually die within two or three weeks. In inoculated plants small brown primary lesions, rapidly increasing in size especially along veins, eventually involve the whole leaf; petiole and stem streak follows. Among garden peas, the varieties Pride of the Market, Little Marvel, Wm. Massey and Autocrat are little affected; among field peas, the varieties Unica and White Ivory are equally resistant. In cucumber, experimentally, numerous brown, necrotic local lesions, each with light colored center and surrounding light-yellow halo. In bean, experimentally, local and systemic necrosis, stem streak, death of plant.

Transmission: By inoculation of expressed juice, best with an abrasive powder such as fine sand. Not by *Myzus persicae* (Sulz.), *Macrosiphum solani* (*APHIDIDAE*), nor *Thrips tabaci* Lind. (*THRIPIDAE*). No insect vector is known.

Thermal inactivation: At 78 to 80° C in 10 minutes.

Filterability: Passes Mandler filters of preliminary, regular, and fine grades.

Other properties: Dilution end point $1:10^6$. Not inactivated at room temperature in 41 days.

Literature: Chamberlain, New Zealand Jour. Science and Technology, *20*, 1939, 365A–381A.

39. **Marmor efficiens** Johnson. (Phytopath., *32*, 1942, 114.) From Latin *efficiens*, effective, in reference to ability of this virus to cause mottling in all tested varieties of pea in contrast with inability of pea-wilt virus, a second constituent of the complex earlier known as "white-clover mosaic virus," to produce such chlorotic symptoms in tested varieties other than Alaska and Canada White.

Common name: Pea-mottle virus.

Hosts: *LEGUMINOSAE*—*Trifolium repens* L., white clover; *Pisum sativum* L., pea. Experimentally, also *CARYOPHYLLACEAE*—*Stellaria media* (L.) Cyrill. *CHENOPODIACEAE*—*Spinacia oleracea* L., spinach. *CUCURBITACEAE*—*Cucumis sativus* L. *LEGUMINOSAE*—*Lathyrus odoratus* L.; *Lens esculenta* Moench.; *Lupinus albus* L.; *L. hirsutus* L.; *Medicago lupulina* L.; *M. sativa* L., alfalfa (lucerne); *Melilotus alba* Desr.; *Phaseolus aureus* Roxb.; *P. vulgaris* L., bean; *Trifolium hybridum* L.; *T. incarnatum* L.; *T. pratense* L.; *Vicia faba* L.; *V. sativa* L. *SCROPHULARIACEAE*—*Antirrhinum majus* L.

Insusceptible species: *CHENOPODIACEAE*—*Beta vulgaris* L., sugar beet. *COMPOSITAE*—*Callistephus chinensis* Nees; *Lactuca sativa* L.; *Taraxacum officinale* Weber; *Zinnia elegans* Jacq. *CRUCIFERAE*—*Barbarea vulgaris* R. Br.; *Brassica oleracea* L.; *Raphanus sativus* L. *GRAMINEAE*—*Zea mays* L. *LEGUMINOSAE*—*Glycine max* Merr.; *Vigna sinensis* (L.) Endl. *LILIACEAE*—*Lilium formosanum* Stapf. *PLANTAGINACEAE* — *Plantago*

lanceolata L.; *P. major* L. *POLYGONACEAE*—*Rumex acetosella* L. *SOLANACEAE*—*Datura stramonium* L.; *Lycopersicon esculentum* Mill.; *Nicotiana glutinosa* L.; *N. rustica* L.; *N. sylvestris* Spegaz. and Comes; *N. tabacum* L.; *Solanum nigrum* L.

Geographical distribution: United States (Washington).

Induced disease: Experimentally, in pea, developing leaves late in opening; clearing of veins, chlorotic spotting, stunting, chlorotic mottling; stipules mottled; stems, pods, and seeds appear normal. If pea-wilt virus (*Marmor repens* Johnson) is also present, a severe streak disease occurs. Intracellular inclusions absent. In bean, light yellow spots and clearing of veins. In spinach, severe chlorotic mottling, dwarfing. In alfalfa, streaks of yellowing along veins, chlorotic mottling.

Transmission: By inoculation of expressed juice. By dodder, *Cuscuta campestris* Yunck. (*CONVOLVULACEAE*). Not by pea aphid, *Macrosiphum pisi* Kalt. (*APHIDIDAE*). No insect vector is known.

Thermal inactivation: At 60 to 62° C in 10 minutes.

Filterability: Passes Berkefeld W filter candle.

Other properties: Infectious in dilution of 1:10,000 and after storage in expressed juice or dried tissues for one month at about 25° C.

Literature: Johnson, Phytopath., *32*, 1942, 103–116; Johnson and Jones, Jour. Agr. Res., *54*, 1937, 629–638; Pierce, *ibid.*, *51*, 1935, 1017–1039; Zaumeyer and Wade, *ibid.*, *51*, 1935, 715–749.

40. **Marmor tritici** H. (*loc. cit.*, 61). From Latin *triticum*, wheat.

Common names: Wheat-mosaic virus, wheat-rosette virus.

Hosts: *GRAMINEAE*—*Triticum aestivum* L., wheat; *Secale cereale* L., rye. Experimentally, also all tested species of the tribe Hordeae; *Triticum compactum* Host; *T. turgidum* L.; *T. durum* Desf.; *T. dicoccum* Schrank; *T. spelta* L.; *T. polonicum* L.; *T. monococcum* L., *Hordeum vulgare* L., barley.

Insusceptible species: *GRAMINEAE*—*Bromus inermis* Leyss., awnless brome-grass (of the tribe *Festuceae*).

Geographical distribution: United States, Japan.

Induced disease: In wheat, systemic chlorotic mottling, with dwarfing in some varieties; vacuolate, rounded intracellular bodies in diseased cells, usually close to nucleus. Some selections of Harvest Queen wheat are resistant.

Transmission: Through soil; remains infectious in soil 6 or more years. By inoculation of expressed juice (needle punctures in stem). Not through seeds or stubble of diseased plants. No insect vector is known.

Thermal inactivation: Contaminated soil becomes incapable of infecting wheat plants if heated for 10 minutes at 60° C though not if heated for the same length of time at 50° C.

Literature: Johnson, Science, *95*, 1942, 610; McKinney, Jour. Agr. Res., *23*, 1923, 771–800; U. S. Dept. Agr., Bull. 1361, 1925; U. S. Dept. Agr., Circ. 442, 1937; Jour. Agr. Res., *40*, 1930, 547–556; McKinney et al., *ibid.*, *26*, 1923, 605–608; Wada and Hukano, Agr. and Hort., *9*, 1934, 1778–1790 (Rev. Appl. Mycol., *14*, 1935, 618, Abst.); Jour. Imp. Agr. Exp. Sta., *3*, 1937, 93–128 (Rev. Appl. Mycol., *16*, 1937, 665, Abst.); Webb, Jour. Agr. Res., *35*, 1927, 587–614; *36*, 1928, 53–75.

41. **Marmor graminis** McKinney. (Jour. Washington Acad. Sci., *34*, 1944, 325.) From Latin *gramen*, grass.

Common name: Brome-grass mosaic virus.

Hosts: *GRAMINEAE*—*Bromus inermis* Leyss., awnless brome-grass. Experimentally, also *Triticum aestivum* L., wheat; *Avena sativa* L., oat.

Geographical distribution: United States (Kansas).

Induced disease: In awnless brome-grass, systemic chlorotic mottling of the

type commonly called yellow mosaic because of the distinctly yellow color of the chlorotic areas in affected leaves.

Transmission: By inoculation of expressed juice or of aqueous suspensions of dried diseased tissues; not inactivated by drying in diseased tissues for at least 51 days. No insect vector is known.

Literature: McKinney et al., Phytopath., *32*, 1942, 331.

42. **Marmor abaca** H. (*loc. cit.*, 63). From common name of host plant.

Common name: Abacá bunchy-top virus.

Host: *MUSACEAE—Musa textilis* Née, abacá (Manila hemp plant).

Insusceptible species: *MUSACEAE—Musa sapientum* L. vars. *cinerea* (Blanco) Teodoro, *compressa* (Blanco) Teodoro, *lacatan* (Blanco) Teodoro, and *suaveolens* (Blanco) Teodoro; *M. cavendishii* Lamb.

Geographical distribution: Philippine Islands.

Induced disease: In abacá (Manila hemp plant), chlorotic lines and spots along veins of young leaves, followed by growth of distorted leaves, successively shorter, narrower, stiffer, and more curled along their margins. The green areas of mottled leaves, petioles, and leaf sheaths are darker than normal. Newly formed diseased leaves unfurl early, but are short, producing the bunchy top that is referred to in the common name of the disease.

Transmission: By the aphid, *Pentalonia nigronervosa* Coq. (*APHIDIDAE*), vector also of the apparently distinct banana bunchy-top virus of Australia. The incubation period of abacá bunchy-top virus in this aphid is between 24 and 48 hours in length. The progeny of viruliferous aphids do not receive the virus directly, but must feed on diseased plants before they can infect healthy abacá. Transmission by inoculation of expressed juice has not been demonstrated. No soil transmission.

Literature: Ocfemia, Am. Jour. Bot., *17*, 1930, 1–18; Philippine Agriculturist, *22*, 1934, 567–581.

43. **Marmor passiflorae** H. (*loc. cit.*, 77). From New Latin *Passiflora*, generic name of passion fruit.

Common name: Passion-fruit woodiness virus.

Hosts: *PASSIFLORACEAE—Passiflora edulis* Sims, passion fruit; *P. coerulea* L. Experimentally, also *P. alba* Link and Otto.

Insusceptible species: *SOLANACEAE—Datura stramonium* L.; *Lycopersicon esculentum* Mill., tomato; *Nicotiana glutinosa* L.; *N. tabacum* L., tobacco.

Geographical distribution: Australia (New South Wales, Queensland, Victoria), Kenya.

Induced disease: In passion fruit, growth checked; leaves puckered, slightly chlorotic or obscurely mottled, curled, twisted, deformed. Clearing of veins has been observed. Color of stems darker green than normal in some places. Fruits short or deformed, discolored, surface sometimes roughened by cracks; so hard as not to be cut through readily. Pericarp or rind of fruit abnormally thick. Pulp deficient, color deepened. At temperatures below 80° F, some abscission of young chlorotic leaves; above 85° F, masking of the disease in most plants.

Transmission: By inserting cotton in stem wound after soaking it in expressed juice of diseased plant. By aphids, *Myzus persicae* (Sulz.), *Macrosiphum solanifolii* Ashm., and two dark-colored species of the genus *Aphis* (*APHIDIDAE*).

Literature: Cobb, Agr. Gaz. New South Wales, *12*, 1901, 407–418; Noble, Jour. and Proc. Roy. Soc. New South Wales, *62*, 1928, 79–98; Noble and Noble, *ibid.*, *72*, 1939, 293–317; Simmonds, Queensland Agr. Jour., *45*, 1936, 322–330.

44. **Marmor flaccumfaciens** H. (*loc. cit.*, 73). From Latin *flaccus*, flabby, and *facere*, to make.

Common names: Rose-wilt virus, rose dieback virus.

Hosts: *ROSACEAE—Rosa* hybrids, roses.

Geographical distribution: Australia, especially Victoria; New Zealand; possibly Italy.

Induced disease: In rose, leaflets crowded, brittle, recurved. Defoliation progresses from tip to base of plant. Tips of branches discolor and die back an inch or two. Stem darkens at base. Buds remain green and begin development, but growth is soon checked by necrosis at tips. Plant may recover temporarily, but not permanently.

Transmission: By inoculation of expressed juice (needle-puncture and scratch methods). No insect vector is known.

Filterability: Passes Seitz filter (Seitz EK Schichten type, size 6).

Literature: Gigante, Boll. Staz. Pat. Veg. Roma, n. s. *16*, 1936, 76–94; Grieve, Austral. Jour. Exp. Biol. and Med. Science, *8*, 1931, 107–121; Jour. Dept. Agr. Victoria, 1932 and 1933, pages 30–32.

45. **Marmor rosae** H. (*loc. cit.*, 74). From Latin *rosa*, rose.

Common name: Rose-mosaic virus.

Hosts: *ROSACEAE—Rosa rugosa* Thunb.; *R. chinensis* Jacq. var. *manetti* Dipp.; *R. multiflora* Thunb.; *R. odorata* Sweet, tea rose; *R. gymnocarpa*; *Rubus parviflorus* Nutt.

Geographical distribution: United States, England, Bulgaria, Brazil.

Induced disease: In *Rosa rugosa* and *R. chinensis* var. *manetti*, systemic chlorotic mottling.

Transmission: By budding and other forms of graftage. Not by inoculation of expressed juice. No insect vector is known.

Literature: Baker and Thomas, Phytopath., *32*, 1942, 321–326; Brierley, Phytopath., *25*, 1935, 8 (Abst.); Brierley and Smith, Am. Nurseryman, *72*, 1940, 5–8; Jour. Agr. Res., *61*, 1940, 625–660; Kramer, Revista de Agricultura, *15*, 1940, 301–311; O Biologico, *6*, 1940, 365–368; McWhorter, U. S. Dept. Agr., Plant Dis. Rep., *15*, 1931, 1–3; Milbrath, West. Florist, *13*, 1930, 29–30; Nelson, Phytopath., *20*, 1930, 130 (Abst.); Newton, Rep. Domin. Bot., 1930, Div. Bot., Canad. Dept. Agr., 1931, 23; Thomas and Massey, Hilgardia, *12*, 1939, 645–663; Vibert, Jour. Soc. Imp. et Cent. Hort., *9*, 1863, 144–145; White, Phytopath., *22*, 1932, 53–69; *24*, 1934, 1124–1125.

46. **Marmor veneniferum** H. (*loc. cit.*, 75). From Latin *venenifer*, poisonous, in reference to occasional killing of tissues near inserted bud in graft transmission.

Common name: Rose-streak virus.

Hosts: *ROSACEAE—Rosa multiflora* Thunb.; *R. odorata* Sweet; *Rosa* hybrids.

Geographical distribution: Eastern United States.

Induced disease: In various rose species and hybrids, brownish or reddish ring and veinbanding patterns on leaves, and ring patterns on stems. Sometimes necrotic areas near inserted bud, causing girdling of stem and wilting of foliage.

Transmission: By grafting. Not by inoculation of expressed juice. No insect vector is known.

Literature: Brierley, Phytopath., *25*, 1935, 7–8 (Abst.); Brierley and Smith, Jour. Agr. Res., *61*, 1940, 625–660.

47. **Marmor mali** H. (*loc. cit.*, 75). From Latin *malus*, apple tree.

Common name: Apple-mosaic virus.

Hosts: *ROSACEAE—Pyrus malus* L., apple. Experimentally, also *Cotoneaster harroviana*; *Eriobotrya japonica* Lindl., loquat; *Photinia arbutifolia* Lindl., toyon; *Rosa* sp., rose; *Sorbus pallescens*.

Insusceptible species: *ROSACEAE—Amelanchier alnifolia* Nutt.; *Crataegus douglasii* Lindl.; *Pyrus communis* L., pear.

Geographical distribution: United States, Australia, Bulgaria, British Isles.

Induced disease: In apple, clearing of veins and systemic chlorotic spotting. The chlorotic areas sometimes become necrotic during months of intense sunlight.

Transmission: By grafting. No insect

vector is known. Transmission by inoculation of expressed juice has not been demonstrated.

Thermal inactivation: Not demonstrated. Virus in stem tissues withstands at least 50° C for as much as 60 minutes without being inactivated.

Literature: Blodgett, Phytopath., *28*, 1938, 937-938; Bradford and Joley, Jour., Agr. Res., *46*, 1933, 901-908; Christoff, Phytopath. Zeitschr., *7*, 1934, 521-536; *8*, 1935, 285-296; Thomas, Hilgardia, *10*, 1937, 581-588.

48. **Marmor fragariae** H. (*loc. cit.*, 78). From New Latin *Fragaria*, generic name of strawberry, from Latin *fraga*, strawberries.

Common name: Strawberry-crinkle virus.

Hosts: *ROSACEAE—Fragaria* hybrids, cultivated strawberries. Experimentally, also *Fragaria vesca* L., woodland strawberry.

Geographical distribution: United States, England.

Induced disease: In cultivated strawberry, crinkling and chlorosis of leaves. At first, minute chlorotic flecks appear in young leaves. These flecks enlarge, and small necrotic spots may appear in their centers. Vein-clearing appears frequently. Affected foliage lighter and less uniformly green than normal. The variety Royal Sovereign may appear normal through carrying this virus.

Transmission: By aphid, *Myzus fragaefolii* Ckll. (= *Capitophorus fragariae* Theob.) (*APHIDIDAE*). By grafting. Not by inoculation of expressed juice.

Literature: Harris, Ann. Rept. East Malling Res. Sta. for 1936, 1937, 201-211, 212-221; *ibid.*, for 1937, 1938, 201-202; Harris and Hildebrand, Canad. Jour. Res., C, *15*, 1937, 252-280; Ogilvie et al., Ann. Rept. Long Ashton Res. Sta. for 1933, 1934, 96-97; Vaughan, Phytopath., *23*, 1933, 738-740; Zeller, Oregon Agr. Exp. Sta., Sta. Bull. 319, 1933; Zeller and Vaughan, Phytopath., *22*, 1932, 709-713.

49. **Marmor marginans** H. (*loc. cit.*, 79). From Latin *marginare*, to provide with a margin.

Common name: Strawberry yellow-edge virus.

Hosts: *ROSACEAE—Fragaria* hybrids, strawberries; *Fragaria californica* C. and S.; *F. chiloensis* Duch. (symptomless). Experimentally, also *Fragaria vesca* L.; *F. virginiana* Duch. (some clones appear to be immune to infection by runner inarching).

Geographical distribution: United States, England, France, New Zealand.

Induced disease: In strawberry, plant appears flat with outer zone of leaves more or less normal, central leaves dwarfed, yellow-edged, deficient in red pigmentation. The variety Premier may carry this virus without showing any obvious manifestation of disease.

Transmission: By aphid, *Myzus fragaefolii* Ckll. (*APHIDIDAE*). By grafting. Not by inoculation of expressed juice. Not through seeds from diseased plants.

Literature: Chamberlain, New Zealand Jour. Agr., *49*, 1934, 226-231; Harris, Jour. Pom. and Hort. Science, *11*, 1933, 56-76; Harris and Hildebrand, Canad. Jour. Res., C, *15*, 1937, 252-280; Hildebrand, *ibid.*, C, *19*, 1941, 225-233; Plakidas, Phytopath., *16*, 1926, 423-426; Jour. Agr. Res., *35*, 1927, 1057-1090.

50. **Marmor rubi** H. (Holmes, *loc. cit.*, 80; *Poecile rubi* McKinney, Jour. Washington Acad. Science, *34*, 1944, 148.) From Latin *rubus*, bramble bush.

Common name: Red-raspberry mosaic virus.

Hosts: *ROSACEAE—Rubus idaeus* L., red raspberry; *R. occidentalis* L., black raspberry.

Geographical distribution: United States.

Induced disease: In red raspberry, systemic chlorotic mottling, masked at high temperatures of summer. Foliage development delayed in spring. In some varieties, leaf petioles and cane tips die,

canes remain short and become rosetted.

Transmission: By aphids, principally *Amphorophora rubi* Kalt., but also *A. rubicola* Oestl. and *A. sensoriata* Mason (*APHIDIDAE*). Not by inoculation of expressed juice.

Literature: Bennett, Michigan Agr. Exp. Sta., Techn. Bull. 80, 1927; 125, 1932; Cooley, New York Agr. Exp. Sta. (Geneva), Bull. 675, 1936; Harris, Jour. Pom. and Hort. Science, *11*, 1933, 237–255; *17*, 1940, 318–343; Rankin, New York Agr. Exp. Sta., Geneva, Bull. 543, 1927; New York Agr. Exp. Sta., Geneva, Tech. Bull. 175, 1931.

51. **Marmor persicae** H. (Holmes, *loc. cit.*, 81; *Flavimacula persicae* McKinney, Jour. Washington Acad. Science, *34*, 1944, 149.) From New Latin *Persica*, former generic name of peach.

Common name: Peach-mosaic virus.

Hosts: *ROSACEAE—Prunus persica* (L.) Batsch, peach and nectarine, all tested varieties. Experimentally, also *P. armeniaca* L., apricot; *P. communis* Fritsch, almond; *P. domestica* L., plum and prune.

Insusceptible species: Attempts to infect sweet and sour cherries have thus far failed.

Geographical distribution: United States (Colorado, California, Utah, Oklahoma, Texas, New Mexico, Arizona).

Induced disease: In peach, short internodes in spring growth, sometimes breaking in flower pattern, chlorotic mottling and distortion of foliage early in season, masking of leaf symptoms or excision of affected areas of leaf lamina in midsummer; fruit small, irregular in shape, unsalable. Some peach varieties are less damaged than others, but all are thought to be equally susceptible to infection, and equally important as reservoirs of virus when infected. In almond, experimentally, symptomless infections; symptoms appear in some apricot and plum varieties when experimentally infected, not in others.

Transmission: By budding and other methods of grafting. Not by inoculation of expressed juice. Not through soil. No insect vector is known. Not through pollen or seed from diseased plants.

Thermal inactivation: Not demonstrated; virus not inactivated by temperatures effective in inactivating peach-yellows virus.

Literature: Bodine, Colorado Agr. Exp. Sta., Bull. 421, 1936; Bodine and Durrell, Phytopath., *31*, 1941, 322–333; Cation, *ibid.*, 24, 1934, 1380–1381; Christoff, Phytopath. Ztschr., *11*, 1938, 360–422; Cochran, California Cultivator, *87*, 1940, 164–165; Cochran and Hutchins, Phytopath., *28*, 1938, 890–892; Hutchins, Science, *76*, 1932, 123; Hutchins et al., U. S. Dept. Agr., Circ. 427, 1937, 48 pp.; Kunkel, Am. Jour. Bot., *23*, 1936, 683–686; Phytopath., *28*, 1938, 491–497; Thomas and Rawlins, Hilgardia, *12*, 1939, 623–644; Valleau, Kentucky Agr. Exp. Sta., Bull. 327, 1932, 89–103.

52. **Marmor astri** H. (*loc. cit.*, 83). From Latin *astrum*, star.

Common name: Peach asteroid-spot virus.

Host: *ROSACEAE—Prunus persica* (L.) Batsch, peach.

Geographical distribution: California.

Induced disease: In peach, discrete chlorotic lesions spreading along veins, forming star-like spots; developing leaves normal in appearance, becoming affected as they mature. Some chlorophyll retained in lesions as leaves turn yellow. Affected leaves shed early.

Transmission: By grafting. Not by inoculation of expressed juice. No insect vector is known.

Literature: Cochran and Smith, Phytopath., *28*, 1938, 278–281.

53. **Marmor rubiginosum** Reeves. (Phytopath., *30*, 1940, 789.) From Latin *rubiginosus*, rusty.

Common name: Cherry rusty-mottle virus.

Host: *ROSACEAE—Prunus avium* L., sweet cherry.

Geographical distribution: United States (Washington).

Induced disease: In sweet cherry, chlorotic mottling 4 to 5 weeks after full bloom, first on small basal leaves, later on all leaves. The older affected leaves develop autumnal colors and absciss, 30 to 70 per cent of the foliage being lost. The remaining foliage appears somewhat wilted, shows increased mottling, chlorotic spots, and areas becoming yellowish brown, appearing rusty. Blossoms normal. Fruits smaller than normal, insipid, not misshapen. Growth rate of tree reduced slightly.

Transmission: By grafting. Not by inoculation of expressed juice. No insect vector is known.

Literature: Reeves, Phytopath., *30*, 1940, 789 (Abst.); Jour. Agr. Res., *62*, 1941, 555–572 (see 566–567).

54. **Marmor cerasi** Zeller and Evans. (Phytopath., *31*, 1941, 467.) From Latin *cerasus*, cherry tree; originally spelled *cerasae*, by error.

Common name: Cherry mottle-leaf virus.

Hosts: *ROSACEAE—Prunus avium* L., sweet cherry; *P. emarginata* (Dougl.) Walp., wild cherry. Experimentally, also *P. cerasus* L. (tolerant) and *P. mahaleb* L. (tolerant).

Geographical distribution: United States (Washington, Oregon, Idaho, California) and Canada (British Columbia).

Induced disease: In sweet cherry, chlorotic mottling; leaves puckered, wrinkled, distorted, not perforated. Blossoms not affected. Fruit small, hard, insipid, uneven or delayed in ripening. Crop reduced. Branches shortened, tree eventually stunted.

Transmission: By budding. No insect vector is known. Not by the black cherry aphid, *Myzus cerasi* (F.) (*APHIDIDAE*). Not by inoculation of expressed juice.

Thermal inactivation: Not demonstrated; not at 46° C in 60 minutes nor at 49° C in 10 minutes in bud sticks.

Literature: Reeves, Washington State Hort. Assoc. Proc., *31*, 1935, 85–89; Jour. Agr. Res., *62*, 1941, 555–572; Zeller, Oregon State Hort. Soc. Report, 26, 1934, 92–95; Phytopath., *31*, 1941, 463–467.

55. **Marmor lineopictum** Cation (Phytopath., *31*, 1941, 1009.) From Latin *linea*, line, and *pictus*, ornamented.

Common names: Prunus line-pattern virus, peach line-pattern virus.

Hosts: *ROSACEAE—Prunus salicina* Lindl., Japanese plum; *P. mahaleb* L., Mahaleb cherry; *P. persica* (L.) Batsch, peach (= *Amygdalus persica* L.).

Geographical distribution: United States (Kentucky, Michigan, California, Ohio; perhaps widely distributed).

Induced disease: In peach and Mahaleb cherry, light-colored line patterns or faint chlorotic mottling, tending to become masked as leaf becomes old. In peach, affected foliage sometimes less glossy than normal. In *Prunus salicina*, no disease manifestations usually; rarely, chlorotic mottling on a few leaves.

Transmission: By grafting. No insect vector is known.

Literature: Berkeley, Div. of Bot. and Plant Path., Science Service, Dominion Dept. Agr., Ottawa, Canada, Publ. 679, 1941; Cation, Phytopath., *31*, 1941, 1004–1010; Thomas and Rawlins, Hilgardia, *12*, 1939, 623–644; Valleau, Kentucky Agr. Exp. Sta., Res. Bull. 327, 1932, 89–103.

56. **Marmor pallidolimbatus** Zeller and Milbrath. (In Handbook of Virus Diseases of Stone Fruits in North America, Michigan Agr. Exp. Sta., Miscell. Publ., May, 1942, 50; Phytopath., *32*, 1942, 635.) From Latin *pallidus*, pale, and *limbatus*, bordered.

Common name: Cherry banded-chlorosis virus.

Hosts: *ROSACEAE—Prunus serrulata* Lindl., flowering cherry; *P. avium* L., Mazzard cherry.

Geographical distribution: United States (Pacific Northwest).

Induced disease: In flowering cherry,

chlorotic bands surrounding discolored areas on leaves. In Mazzard cherry, dwarfing of whole plant, chlorotic bands on leaves.

Transmission: By budding, even in the absence of survival of inserted buds.

57. **Marmor nerviclarens** Zeller and Evans. (Phytopath., *31*, 1941, 467.) From Latin *nervus*, sinew or nerve, and *clarere*, to shine.

Common name: Cherry vein-clearing virus.

Hosts: *ROSACEAE—Prunus avium* L., sweet cherry. Perhaps also *P. serrulata* Lindl. and *P. domestica* L., on which symptoms similar to those induced by this virus have been observed.

Geographical distribution: United States (Oregon, Washington).

Induced disease: In sweet cherry, clearing of veins throughout each leaf or only in localized areas. Margins of leaves irregular, most indented where clearing of veins is most conspicuous. Elongated, elliptic, or slot-like perforations occur in some leaves. Affected leaves usually narrow. Enations occur as small blistered proliferations on lower side of main veins. Upper leaf surface silvery by reflected light. By midsummer, leaves droop and appear somewhat wilted; they may fold along the midvein. Internodes short; increased number of buds, spurs, or short branches at nodes; rosetting more pronounced on some branches than on others, mostly at end of year-old wood. In advanced disease, fruits pointed, small, flattened on suture side with swollen ridge along suture. Blossoms abnormally abundant, crop of fruit reduced or wanting.

Transmission: By grafting. Not demonstrated by inoculation of expressed juice. No insect vector is known.

58. **Marmor viticola** H. (*loc. cit.*, 83). From Latin *vitis*, vine, and *-cola*, inhabitant of.

Common name: Vine-mosaic virus.

Host: *VITACEAE—Vitis vinifera* L., grape.

Geographical distribution: France, Italy, Bulgaria, Czechoslovakia.

Induced disease: In grape, various modifications of systemic chlorotic mottling, and red pigmentation of parts of leaves with subsequent drying and dropping out of affected spots. Leaves deformed, crimped between main veins. Growth restricted.

Transmission: By inoculation of expressed juice and by pruning.

Literature: Blattný, Vinařský obzor., *25*, 1931, 4–5 (Cent. f. Bakt., II Abt., *84*, 1931, 464); Ochrana Rostlin, *13*, 1933, 104–105 (Rev. Appl. Mycol., *13*, 1934, 421); Gigante, Boll. Staz. Pat. Veg. Roma, n. s. *17*, 1937, 169–192 (Rev. Appl. Mycol., *17*, 1938, 221); Pantanelli, Malpighia, *24*, 1911, 497–523; *25*, 1912, 17–46; Stranak, II Congr. Intern. Path. Comp. Paris, 1931, 367–378; Ochrana Rostlin, *11*, 1931, 89–98 (Rev. Appl. Mycol., *11*, 1932, 280); Vielwerth, Ochrana Rostlin, *13*, 1933, 83–90 (Rev. Appl. Mycol., *13*, 1934, 421–422).

59. **Marmor santali** H. (*loc. cit.*, 94). From New Latin, *Santalum*, generic name of sandal.

Common name: Sandal leaf-curl virus.

Host: *SANTALACEAE—Santalum album* L., sandal.

Geographical distribution: India.

Induced disease: In sandal, leaves small, curled, wrinkled, thickened, brittle, abscissing. Systemic chlorotic mottling. Internode length normal. Infected twigs produce both flowers and fruits.

Transmission: By ring bark-grafts. Not by inoculation of expressed juice. No insect vector is known.

Literature: Venkata Rao, Mysore Sandal Spike Invest. Comm., Bull. 3, 1933.

60. **Marmor secretum** Bennett. (Phytopath., *34*, 1944, 88). From Latin *secretus*, hidden.

Common name: Dodder latent-mosaic virus.

Hosts: *CONVOLVULACEAE—Cuscuta californica* Choisy, dodder. Experi-

mentally, also *CHENOPODIACEAE—Beta vulgaris* L., sugar beet; *Chenopodium album* L., lamb's quarters; *C. murale* L., sowbane. *CONVOLVULACEAE—Cuscuta campestris* Yuncker; *C. subinclusa* Dur. and Hilg. *CRUCIFERAE—Brassica incana* (L.) F. W. Schultz, mustard (tolerant). *CUCURBITACEAE—Cucumis melo* L., cantaloupe. *PHYTOLACCACEAE—Phytolacca americana* L., pokeweed. *PLANTAGINACEAE—Plantago major* L., plantain. *POLYGONACEAE—Fagopyrum esculentum* Moench, buckwheat; *Polygonum pennsylvanicum* L., knotweed. *PRIMULACEAE—Samolus floribundus* HBK., water pimpernel. *SOLANACEAE—Lycopersicon esculentum* Mill., tomato; *Nicotiana glauca* Graham (tolerant); *N. palmeri* Gray; *N. rustica* L. (tolerant); *N. tabacum* L. (tolerant); *Solanum tuberosum* L., potato. *UMBELLIFERAE—Apium graveolens* L., celery.

Insusceptible species: *COMPOSITAE—Helianthus annuus* L., sunflower; *Lactuca sativa* L., lettuce. *CRUCIFERAE—Brassica oleracea* L., cabbage. *POLYGONACEAE—Eriogonum fasciculatum* Benth., California buckwheat. *SCROPHULARIACEAE—Verbascum thapsus* L., mullein. *SOLANACEAE—Atropa belladonna* L., belladonna.

Geographical distribution: United States (California).

Induced disease: In dodder, no symptoms. In sugar beet, experimentally, temporary systemic chlorotic spotting; occasional faded areas in leaves in subsequent chronic stage of disease. In cantaloupe, experimentally, chlorotic spotting, reduction in leaf size, death of some leaves, stunting of plant; melons small and of poor quality. In celery, experimentally, systemic chlorosis followed by dwarfing and mottling with subsequent apparent recovery.

Transmission: By dodder, *Cuscuta californica*, *C. campestris*, and *C. subinclusa*. By inoculation of extracted juice to some, but not to other, host plants; *Phytolacca americana* is readily infected by rubbing methods in the presence of a small amount of abrasive, and develops numerous necrotic primary lesions that serve for quantitative estimation of concentration of virus in inoculum. Through seeds from infected plants of dodder, *Cuscuta campestris*; not through seeds from diseased cantaloupe, buckwheat, or pokeweed plants. No insect vector is known.

Thermal inactivation: At 56 to 60° C in 10 minutes.

Filterability: Passes celite and Berkefeld N and W filters.

Other properties: Infective in dilutions to 1:3000. Inactivated by drying and by storage in expressed pokeweed juice, within 48 hours.

61. **Marmor pelargonii** *spec. nov.* From New Latin *Pelargonium*, generic name of common geranium.

Common names: Pelargonium leaf-curl virus; virus of dropsy or Kräuselkrankheit of geranium.

Host: *GERANIACEAE—Pelargonium hortorum* Bailey, geranium.

Induced disease: In geranium, circular or irregular chlorotic spots, sometimes stellate or dendritic, ½ to 5 mm in diameter, centers becoming brown with chlorotic border; severely affected leaves become yellow and drop; spotted leaves ruffled, crinkled, malformed, small, sometimes puckered and splitting. Petioles and stems show corky, raised, necrotic streaks; tops may die. Disease most severe in spring, inconspicuous in summer.

Transmission: By grafting. Not by inoculation of expressed juice nor by use of knife to prepare cuttings for propagation. Not through seed. No insect vector is known.

Literature: Berkeley, Canad. Hort. and Home Mag., *1938*, 1938, 1–4; Blattný, Ochrana Rostlin, *13*, 1933, 145 (Rev. Appl. Mycol., *13*, 1934, 378–379); Bremer, Blumen-u. Pflanzenbau, *48*, 1933, 32–33 (Rev. Appl. Mycol., *12*, 1933, 514); Halstead, New Jersey Agr. Exp. Sta., Rept. 14, 1893, 432–433; Jones, Washington Agr. Exp. Sta., Bull. 390, 1940;

Laubert, Gartenwelt, *31*, 1927, 391; Pape, *ibid.*, *26*, 1927, 329–331; *32*, 1928, 116–117; Pethybridge and Smith, Gard. Chron., *92*, 1932, 378–379; Schmidt, Gartenwelt, *81*, 1932, 40; Seeliger, Nachrichtenbl. Deutsch. Pflanzenschutzdienst, *6*, 1926, 63–64; Tuimann, Gartenwelt, *31*, 1927, 375–376; Verplancke, Bul. Cl. Sci. Acad. Roy. de Belgique, Ser. 5, *18*, 1932, 269–281 (Rev. Appl. Mycol., *11*, 1932, 649–650).

62. **Marmor angliae** H. (*loc. cit.*, 48). From Latin *Anglia*, England.

Common name: Potato-paracrinkle virus.

Hosts: *SOLANACEAE—Solanum tuberosum* L., potato. Experimentally, also *Datura stramonium* L., Jimson weed.

Insusceptible species: *SOLANACEAE—Nicotiana tabacum* L., tobacco.

Geographical distribution: England.

Induced disease: In potato, masked in all plants of the variety King Edward. Chlorotic mottling with some necrosis in the varieties Arran Victory and Arran Chief. Chlorotic mottling only in Arran Comrade, Majestic, and Great Scot potatoes. Two varieties, Sharpe's Express and Epicure, are said to be resistant.

Transmission: By grafts. Not by inoculation of expressed juice. No insect vector is known.

Literature: Dykstra, Phytopath., *26*, 1936, 597–606; Salaman and Le Pelley, Proc. Roy. Soc. London, Ser. B, *106*, 1930, 140–175.

63. **Marmor aevi** *spec. nov.* From Latin *aevum*, old age, in reference to the obvious involvement of old, but not of young, delphinium leaves.

Common name: Celery-calico virus.

Hosts: *CUCURBITACEAE—Cucumis sativus* L., cucumber; *C. melo* L., cantaloupe; *Cucurbita pepo* L., summer crookneck squash. *RANUNCULACEAE—Delphinium chinensis*; *D. formosum*, hardy larkspur; *D. grandiflorum; D. parryi; D. zalil. SOLANACEAE—Lycopersicon esculentum* Mill., tomato. *UMBELLIFERAE—Apium graveolens* L., celery. Experimentally, also *SOLANACEAE—Nicotiana tabacum* L., tobacco; *Petunia hybrida* Vilm., petunia. *VIOLACEAE—Viola cornuta* L.

Geographical distribution: United States.

Induced disease: In celery, clearing of veins, puckering and downward cupping of younger leaves, green islands of tissue in lemon-yellow areas of outer leaves, green and yellow zigzag bands on leaflets. In delphinium, basal and middle leaves with pale-orange, amber, or lemon-yellow areas; younger leaves normal green; chlorotic ring and line patterns.

Transmission: By inoculation of expressed juice in the presence of finely powdered carborundum. By aphids: *Aphis apigraveolens* Essig, celery leaf aphid; *A. apii* Theob., celery aphid; *A. ferruginea-striata* Essig, rusty-banded aphid; *A. gossypii* Glov., cotton aphid; *A. middletonii* Thomas, erigeron root aphid; *Myzus circumflexus* (Buckt.), lily aphid; *M. convolvuli* (Kalt.), foxglove aphid; *M. persicae* (Sulz.), green peach aphid; *Rhopalosiphum melliferum* (Hottes), honeysuckle aphid (*APHIDIDAE*).

Literature: Severin, Hilgardia, *14*, 1942, 441–464; Severin and Freitag, Phytopath., *25*, 1935, 891 (Abst.); Hilgardia, *11*, 1938, 493–558.

64. **Marmor raphani** *spec. nov.* From Latin *raphanus*, radish.

Common name: Radish-mosaic virus.

Hosts: *CRUCIFERAE—Raphanus sativus* L., radish. Experimentally, also *CRUCIFERAE—Brassica oleracea* L.; *B. nigra* (L.) Koch; *B. alba* (L.) Boiss; *B. arvensis* (L.) Ktze.; *B. pe-tsai* Bailey; *B. juncea* (L.) Coss; *B. rapa* L.; *B. adpressa* Boiss; *Capsella bursa-pastoris* (L.) Medic.; *Malcomia maritima* R. Br.; *M. bicornis* DC. *CHENOPODIACEAE—Chenopodium album* L.; *C. murale* L.; *Spinacia oleracea* L. *RANUNCULACEAE—Delphinium ajacis* L. *SOLANACEAE—Nicotiana glutinosa* L.; *N.*

langsdorffii Weinm.; *N. rustica* L.; *N. tabacum* L.

Geographical distribution: United States (California).

Induced disease: In radish, systemic chlorotic spotting followed by chlorotic mottling of foliage; little or no leaf distortion; plants not stunted.

Transmission: By inoculation of expressed juice. No insect vector is known; not by the cabbage aphid, *Brevicoryne brassicae* (L.); the false cabbage aphid, *Lipaphis pseudobrassicae* (Davis); or the green peach aphid, *Myzus persicae* (Sulz.) (*APHIDIDAE*). Not through seeds from diseased radish plants.

Thermal inactivation: At 65 to 68° C in 10 minutes.

Literature: Tompkins, Jour. Agr. Res., *58*, 1939, 119–130.

65. **Marmor primulae** *spec. nov.* From New Latin *Primula*, generic name of primrose.

Common name: Primrose-mosaic virus.

Hosts: *PRIMULACEAE—Primula obconica* Hance. Experimentally, also *P. malacoides* Franch. and *P. sinensis* Lindl.

Insusceptible species: *BEGONIACEAE—Begonia semperflorens* Link and Otto. *BORAGINACEAE—Myosotis alpestris* Schmidt. *CAMPANULACEAE—Campanula medium* L. *CARYOPHYLLACEAE—Dianthus barbatus* L. *CHENOPODIACEAE—Spinacia oleracea* L. *COMPOSITAE—Bellis perennis* L.; *Callistephus chinensis* Nees; *Gerbera jamesonii* Hook.; *Lactuca sativa* L.; *Senecio cruentus* DC.; *Tagetes patula* L. *CRUCIFERAE—Brassica oleracea* L.; *B. pe-tsai* Bailey; *B. rapa* L.; *Matthiola incana* R. Br.; *Raphanus sativus* L. *CUCURBITACEAE—Cucumis sativus* L.; *Cucurbita pepo* L. *EUPHORBIACEAE—Ricinus communis* L. *GRAMINEAE—Zea mays* L. *LEGUMINOSAE—Pisum sativum* L.; *Vicia faba* L.; *Vigna sinensis* (Torner) Savi. *LOBELIACEAE—Lobelia hybrida* Hort. *PAPAVERACEAE—Papaver orientale* L. *PRIMULACEAE—Anagallis arvensis* L.; *Cyclamen indicum* L.; *Primula auricula* L.; *P. veris* L. *RANUNCULACEAE—Anemone coronaria* L.; *Delphinium cultorum* Voss; *Ranunculus asiaticus* L. *RESEDACEAE—Reseda odorata* L. *ROSACEAE—Geum chiloense* Balb. *SCROPHULARIACEAE—Antirrhinum majus* L.; *Pentstemon barbatus* Nutt. *SOLANACEAE—Capsicum frutescens* L.; *Datura stramonium* L.; *Lycopersicon esculentum* Mill.; *Nicotiana glutinosa* L.; *N. tabacum* L.; *Solanum tuberosum* L. *TROPAEOLACEAE—Tropaeolum majus* L. *UMBELLIFERAE—Apium graveolens* L. *VERBENACEAE—Verbena hybrida* Voss. *VIOLACEAE—Viola tricolor* L.

Geographical distribution: United States (California).

Induced disease: In *Primula obconica*, chlorosis, stunting, rugosity with upward, or occasionally downward, cupping of leaves. Petioles and peduncles shortened; flowers reduced in size, broken in color (white-streaked). Leaves coarsely mottled with yellow-green, leaving green islands; tips of leaves sometimes narrowed.

Transmission: By inoculation of expressed juice, in the presence of 600-mesh powdered carborundum. Not by aphids, *Myzus persicae* (Sulz.) and *M. circumflexus* (Buckt.) (*APHIDIDAE*). No insect vector is known. Probably not through seeds.

Thermal inactivation: At 50° C, not 48° C, in 10 minutes.

Other properties: Infective after 24, not 48, hours *in vitro*. Infective after 1:10 dilution.

Literature: Tompkins and Middleton, Jour. Agr. Res., *63*, 1941, 671–679.

66. **Marmor caricae** (Condit and Horne) *comb. nov.* (*Ficivir caricae* Condit and Horne, Phytopath., *31*, 1941, 563.) From Latin *carica*, a kind of dried fig.

Common name: Fig-mosaic virus.

Hosts: *MORACEAE—Ficus carica* L.,

fig; *F. altissima* Blume; *F. krishna*; and *F. tsiela* Roxb.

Geographical distribution: United States (California, Texas), England, Puerto Rico, China, New South Wales, Western Australia.

Induced disease: In fig, systemic chlorotic spotting and mottling of foliage; some severe leaf distortion. Fruits sometimes affected, bearing light circular areas, rusty spots, being deformed or dropped prematurely. Necrotic lesions on profichi of Samson caprifigs also have been attributed to action of this virus.

Transmission: By budding. No insect vector is known; mites have been suspected as possible vectors.

Literature: Condit and Horne, Phytopath., *23*, 1933, 887–896; *31*, 1941, 561–563; *33*, 1943, 719–723; Ho and Li, Lingnan Science Jour., *15*, 1936, 69–70; Pittman, W. Austral. Dept. Agr. Jour., *12*, 1935 196.

67. **Marmor italicum** (Fawcett) *comb. nov.* (*Citrivir italicum* Fawcett, Phytopath., *31*, 1941, 357.) Specific epithet meaning "pertaining to Italy."

Common name: Citrus infectious-mottling virus.

Host: *RUTACEAE—Citrus aurantium* L., sour orange.

Geographical distribution: Italy.

Induced disease: In sour orange, white, pale green, or yellow irregular areas in leaves, leaving narrow green bands along midrib; leaves blistered and distorted.

Transmission: The aphid, *Toxoptera aurantii* (Phytopath., *24*, 1934, 661), has been suspected as vector.

Literature: Fawcett, Phytopath., *31*, 1941, 356–357; Petri, Bol. Staz. Pat. Veg. Roma, n. s. *11*, 1931, 105–114.

Note: Several additional species were described too late for complete systematic treatment here. They are plain's wheat mosaic virus, **Marmor campestre** McKinney (Jour. Washington Acad. Sci., *34*, 1944, 324) with varieties *typicum* McKinney and *galbinum* McKinney, respectively causing light-green mosaic and severe yellow mosaic of wheat in Kansas; wheat streak-mosaic virus, **Marmor virgatum** McKinney (*ibid.*, *34*, 1944, 324) with varieties *typicum* McKinney and *viride* McKinney (*ibid.*, *34*, 1944, 325), respectively causing yellow streak-mosaic and green streak-mosaic of wheat in Kansas; Agropyron-mosaic virus, **Marmor agropyri** McKinney (*ibid.*, *34*, 1944, 326), with varieties *typicum* McKinney and *flavum* McKinney, respectively causing green-mosaic mottling and yellow-mosaic mottling in the grass *Agropyron repens* (L.) Beauv. in Virginia; also a virus, **Flavimacula ipomeae** Doolittle and Harter (Phytopath., *35*, 1945, 703), causing feathery mottle of sweet potato in Maryland [see *Marmor persicae* for treatment of a virus that was assigned as type of *Flavimacula* McKinney (Jour. Washington Acad. Sci., *34*, 1944, 149), a genus originally differentiated from *Marmor* as containing viruses not yet inoculable save by tissue union; a natural group of viruses may be represented but their characteristics and affiliations seem not yet clear].

Genus II. **Acrogenus** *Holmes.*

(*Loc. cit.*, 110.)

Viruses of the Spindle-Tuber Group, inducing diseases characterized by abnormal growth habit of host plants without chlorotic or necrotic spotting, systemic chlorosis, witches'-broom formation, or production of galls. Generic name from Greek, meaning point- or peak-producing, in reference to shape of potatoes affected by potato spindle-tuber virus.

The type species is *Acrogenus solani* Holmes.

Key to the species of genus **Acrogenus.**

I. Infecting potato.
1. *Acrogenus solani.*

II. Infecting black currant.
2. *Acrogenus ribis.*

1. **Acrogenus solani** Holmes. (Handb. Phytopath. Viruses, 1939, 111.) From New Latin *Solanum*, generic name of potato.

Common names: Potato spindle-tuber virus, potato spindling-tuber virus, potato marginal leaf-roll virus.

Host: *SOLANACEAE—Solanum tuberosum* L., potato.

Geographical distribution: United States and Canada.

Induced disease: Plants erect, stiff, spindly, lacking vigor. Leaves small, erect, darker green than normal. Petioles sometimes slender, brittle. Tubers long, cylindrical, irregular in shape, tapered at ends, smooth and tender-skinned, of softer than normal flesh in spring. Eyes of tuber conspicuous.

Transmission: By inoculation of expressed juice; by use of contaminated knife in cutting successive tubers before planting; by contacts of freshly cut seed pieces. By aphids, *Myzus persicae* (Sulz.) and *Macrosiphum solanifolii* Ashm. (= *M. gei* Koch) (*APHIDIDAE*). Also by certain leaf-eating insects.

Thermal inactivation: At 60 to 65° C in 10 minutes (in tuber tissues).

Literature: Bald et al., Phytopath., *31*, 1941, 181–186; Folsom, Maine Agr. Exp. Sta., Orono, Bull. 312, 1923; Goss, Phytopath., *16*, 1926, 233, 299–303; *18*, 1928, 445–448; Nebraska Agr. Exp. Sta., Res. Bull. *47*, 1930; *53*, 1931; Jaczewski, La Défense des Plantes, Leningrad, *4*, 1927, 62–77 (Rev. Appl. Mycol., *6*, 1927, 572–573, Abst.); McLeod, Canad. Exp. Farms, Div. Bot., Rpt. for 1926, 1927.

Strains: A strain causing unmottled curly dwarf of potato has been given a varietal name to distinguish it from the type, var. *vulgaris* H. (*loc. cit.*, 111):

1a. *Acrogenus solani* var. *severus* H. (*loc. cit.*, 112). Inducing symptoms in potato on the whole more severe than those caused by the type strain.

Common name: Unmottled curly-dwarf strain of potato spindle-tuber virus. (Goss, Nebraska Agr. Exp. Sta., Res. Bull. 47, 1930; *53*, 1931; Schultz and Folsom, Jour. Agr. Res., *25*, 1923, 43–118.)

2. **Acrogenus ribis** H. (*loc. cit.*, 112). From Latin *ribes*, currant.

Common name: Black-currant reversion-disease virus.

Host: *SAXIFRAGACEAE—Ribes nigrum* L., European black currant.

Geographical distribution: British Isles.

Induced disease: In European black currant, leaves abnormally narrow and flat, small veins few. Flowers sometimes nearly transparent, smooth, sepals brightly colored beneath. Flowers and small fruits fall. Stems less woody than normal, with tendency to excessive gum production.

Transmission: By grafting. By big-bud mite, *Eriophyes ribis* (*ERIOPHYIDAE*). Not by inoculation of expressed juice. Not through soil. Not through seeds from diseased plants.

Literature: Amos and Hatton, Jour. Pom. and Hort. Science, *6*, 1926, 167–183; Amos et al., in East Malling Res. Sta., 15th Ann. Rpt., 1928, 43–46; Lee, Ann. Appl. Biol., *9*, 1935, 49–68.

Genus III. Corium *Holmes.*

(*Loc. cit.*, 119.)

Viruses of the Leaf-Roll Group, inducing diseases usually characterized by thicken-

ing and rolling of leaves. Foliage leathery. Sometimes conspicuous phloem necrosis. Generic name from Latin *corium*, leather.

The type species is *Corium solani* Holmes.

Key to the species of genus **Corium.**

I. Infecting potato.
   1. *Corium solani.*

II. Infecting beet.
   2. *Corium betae.*

III. Infecting raspberry.
   3. *Corium rubi.*
   4. *Corium ruborum.*

1. **Corium solani** Holmes. (Handb. Phytopath. Viruses, 1939, 120.) From New Latin *Solanum*, generic name of potato.

Common name: Potato leaf-roll virus.

Hosts: *SOLANACEAE—Solanum tuberosum* L., potato. Experimentally, also other solanaceous species, *Datura stramonium* L., Jimson weed; *Lycopersicon esculentum* Mill., tomato; *Solanum dulcamara* L., bittersweet; *S. villosum.*

Insusceptible species: *CHENOPODIACEAE—Beta vulgaris* L., beet.

Geographical distribution: North America, France, British Isles; probably wherever potatoes are grown.

Induced disease: In potato, leaves thick, rigid, leathery, and rolled, their starch content excessive. Plants dwarfed. Tubers few, small, crisp. Tubers of some varieties show conspicuous phloem necrosis, germinate with spindling sprouts.

Transmission: By aphid, *Myzus persicae* (Sulz.) (*APHIDIDAE*), with incubation period of 24 to 48 hours. Also by *Myzus convolvuli* (Kalt.) (= *M. pseudosolani* Theob.), *M. circumflexus* (Buckt.), *Macrosiphum solanifolii* Ashm., and *Aphis abbreviata* Patch (*APHIDIDAE*). By grafting. Not by inoculation of expressed juice.

Literature: Artschwager, Jour. Agr. Res., *15*, 1918, 559–570; *24*, 1923, 237–245; Dykstra, *ibid.*, *47*, 1933, 17–32; Elze, Phytopath., *21*, 1931, 675–686; Folsom, Maine Agr. Exp. Sta., Bull. 297, 1921, 37–52; *410*, 1942, 215–250; Murphy, Scient. Proc. Roy. Dublin Soc., *17*, 1923, 163–184; Murphy and M'Kay, *ibid.*, *19*, 1929, 341–353; Schultz and Folsom, Jour. Agr. Res., *21*, 1921, 47–80; Smith, Ann. Appl. Biol., *16*, 1929, 209–229; *18*, 1931, 141–157; Stevenson et al., Am. Potato Jour., *20*, 1943, 1–10.

2. **Corium betae** *spec. nov.* From Latin *beta*, beet.

Common names: Sugar-beet yellows virus, beet-yellows virus, jaunisse virus, vergelingsziekte virus.

Hosts: *CHENOPODIACEAE—Beta vulgaris* L., beet; *B. maritima* L.; *B. cicla*; *Atriplex hortensis* L.; *A. sibirica* L.; *Chenopodium album* L., lamb's quarters; *Spinacia oleracea* L., spinach. *AMARANTHACEAE —Amaranthus retroflexus* L.

Insusceptible species: *SOLANACEAE—Solanum tuberosum* L., potato; all other tested solanaceous species.

Geographical distribution: Belgium, Netherlands, Denmark, England; perhaps Germany and the United States.

Induced disease: In beet, young leaves little affected; older leaves yellow, brittle, short, thick, containing excessive amounts of carbohydrates; necrosis in secondary phloem. In spinach, yellowing, necrosis between veins on old leaves.

Transmission: Not by inoculation of expressed juice. By aphids, *Myzus persicae* (Sulz.), *Aphis fabae* Scop., *Macrosiphum solanifolii* Ashm., and *Aulacor-*

thum solani Kalt. (*APHIDIDAE*); virus is not transmitted by these aphids to their descendants. Not through seeds of beet. Virus overwinters in beets stored for subsequent use in seed production.

Serological relationships: Specific precipitating antiserum effective with crude sap of diseased, not healthy, plants and with sap of diseased plants after passage through a Chamberland L_1, not L_3, filter candle; ineffective with sap from beet plants suffering from mosaic.

Thermal inactivation: Virus heated to about 52°C no longer precipitates with specific antiserum.

Literature: Kleczkowski and Watson, Ann. Appl. Biol., *31*, 1944, 116–120; Petherbridge and Stirrup, London, Ministry Agr. and Fisheries, Bull. *93*, 1935; Quanjer and Roland, Tijdschr. Plantenziekten, *42*, 1936, 45–70; Roland, *ibid.*, *45*, 1939, 1–22, 181–203; Schreven, Meded. Inst. voor Suikerbietenteelt, Bergen op Zoom, *6*, 1936, 1; Watson, Proc. Roy. Soc. London, Ser. B, *128*, 1940, 535–552; Ann. Appl. Biol., *29*, 1942, 358–365.

3. **Corium rubi** H. (*loc. cit.*, 121). From New Latin *Rubus*, generic name of raspberry, from Latin *rubus*, bramble bush.

Common name: Raspberry leaf-curl virus.

Host: *ROSACEAE—Rubus idaeus* L., red raspberry.

Insusceptible species: *ROSACEAE—Rubus occidentalis* L., black raspberry; *R. neglectus* Peck, purple raspberry.

Geographical distribution: United States, not in England.

Induced disease: In red raspberry, veins retarded in growth, causing downward curling of leaf margins and crinkling of leaf lamina. Foliage dark green, dry in appearance, not wilting readily. In late summer, leaves bronzed, leaf surface glistening. Diseased canes easily winter-killed. Berries small and poor. The English variety Lloyd George is intolerant of the disease and is killed.

Transmission: By aphid, *Aphis rubicola* Oestl. (= *A. rubiphila* Patch) (*APHIDIDAE*). Not by inoculation of expressed juice.

Literature: Bennett, Michigan Agr. Exp. Sta., Tech. Bull. 80, 1927; Phytopath., *20*, 1930, 787–802, Harris, East Malling Res. Sta., Ann. Rpt. for 1934, 1935; Rankin, New York Agr. Exp. Sta., Geneva, Tech. Bull. 175, 1931.

Strains: A strain differing from the type, var. *alpha* H. (*loc. cit.*, 121), has been given a varietal name derived from its common name, raspberry beta-curl virus:

3a. *Corium rubi* var. *beta* H. (*loc. cit.*, 122). Infecting black and purple raspberries, as well as the red raspberry, which alone is susceptible to the type strain, raspberry alpha-curl virus. (Bennett, Phytopath., *20*, 1930, 787–802.)

4. **Corium ruborum** (Zeller and Braun) *comb. nov.* (*Minuor ruborum* Zeller and Braun, Phytopath., *33*, 1943, 161.) From Latin *rubus*, bramble bush.

Common name: Raspberry decline-disease virus.

Host: *ROSACEAE—Rubus idaeus* L., red raspberry.

Geographical distribution: United States (Oregon).

Induced disease: In Cuthbert raspberry, shoots retarded in spring, reddish; leaves in autumn rolled downward, fluted along veins, less green than normal between veins, slightly bronzed along margins and crests between veins. Internodes shortened near tips of canes. Affected canes small, weak, not hardy in winter. Small roots and feeder rootlets fewer than in healthy plants. Disease progressive over about three years. Fruits small, irregular, tending to be globose, crumbly when ripe, worthless.

Transmission: By grafting. No insect vector is known.

Genus IV. **Nanus** *Holmes.*

(*Loc. cit.*, 123.)

Viruses of the Dwarf-Disease Group, inducing diseases characterized by dwarfing of host plants or by growth of adventitious shoots with short internodes; chlorotic mottling absent. Generic name from Latin *nanus*, dwarf.

The type species is *Nanus loganobacci* Holmes.

Key to the species of genus **Nanus.**

I. Infecting rosaceous plants.

A. In loganberry and Phenomenal berry.
   1. *Nanus loganobacci.*

B. In black raspberry.
   2. *Nanus orientalis.*

C. In peach.
   3. *Nanus mirabilis.*

D. In ocean spray.
   4. *Nanus holodisci.*

E. In strawberry.
   5. *Nanus fragariae.*
   6. *Nanus cupuliformans.*

F. In prune and plum.
   7. *Nanus pruni.*

II. Infecting graminaceous plants.

A. In sugar cane.
   8. *Nanus sacchari.*

1. **Nanus loganobacci** Holmes. (Handb. Phytopath. Viruses, 1939, 124.)

From New Latin *loganobaccus*, specific epithet of loganberry, *Rubus loganobaccus* Bailey.

Common name: Loganberry-dwarf virus.

Hosts: *ROSACEAE—Rubus loganobaccus* Bailey, loganberry and Phenomenal berry.

Geographical distribution: United States (Oregon, Washington, and California).

Induced disease: In Phenomenal berry, leaves small, obovate, rigid, new canes short, spindly. In young plants, some necrosis along and between veins, leaves crinkled, finer veins chlorotic. Stems not streaked or mottled, normal in color. In late stages, canes very short, internodes short. Sepals and petals of flowers small. Fruit of fair size, but druplets ripen unevenly and tend to fall apart when picked. Loganberry is less susceptible than the Phenomenal berry but is similarly affected.

Transmission: By aphid, *Capitophorus tetrahodus* (*APHIDIDAE*). Not by inoculation of expressed juice.

Literature: Zeller, Phytopath., *15*, 1925, 732 (Abst.); *17*, 1927, 629–648.

2. **Nanus orientalis** H. (*loc. cit.*, 124).

From Latin *orientalis*, eastern.

Common names: Raspberry-streak virus, raspberry eastern blue-stem virus, raspberry rosette virus.

Host: *ROSACEAE—Rubus occidentalis* L., black raspberry.

Insusceptible species: *ROSACEAE—Rubus idaeus* L., red raspberry; *R. phoenicolasius* Maxim., Japanese wineberry.

Geographical distribution: United States.

Induced disease: In black raspberry, plants stunted, becoming smaller in successive seasons; leaves usually curled, close together on canes, dark green, often twisted so as to be upside down. New canes show bluish violet dots, spots, or stripes near their bases and sometimes also on branches or on fruiting spurs.

Fruit inferior in size, quality, and quantity. Plants live only 2 or 3 years after infection on the average.

Strains: A strain of this virus is believed responsible for mild streak of black raspberries, in which purple to violet, greenish brown, or bluish streaks on canes are narrowly linear or elliptical in form and often very faint; when the bloom is rubbed off, the lesions appear as though watersoaked and discolored. Leaves are slightly curled, their veins cleared. Fruits are dry and dull in lustre, even while still red, and of poor flavor when ripe.

Literature: Bennett, Michigan Agr. Exp. Sta., Tech. Bull. 80, 1927; Wilcox U. S. Dept. Agr., Dept. Circ. 227, 1923; Woods and Haut, U. S. Dept. Agr., Plant Dis. Rpt., *24*, 1940, 338–340.

3. **Nanus mirabilis** H. (*loc. cit.*, 126). From Latin *mirabilis*, strange.

Common name: Peach phony-disease virus.

Hosts: *ROSACEAE—Prunus persica* (L.) Batsch, peach. Experimentally, also other *Prunus* species.

Geographical distribution: United States (Georgia, Alabama, Florida; sparsely als› in Mississippi, Tennessee, South Carolina, Louisiana, Texas, Arkansas, Missouri).

Induced disease: In peach, tree dwarfed, foliage abnormally green, fruit small; flecks in wood, especially in roots; sections of roots show characteristic well-distributed purple spots after 3 to 5 minutes of treatment in 25 cc absolute methyl alcohol acidulated by the addition of 1 to 5 drops of concentrated, chemically pure hydrochloric acid.

Transmission: By root grafting, except by root-bark patch grafts, which are ineffective. Budding and grafting with parts of stem fail to transmit this virus.

Thermal inactivation: At 48° C in about 40 minutes in roots.

Literature: Hutchins, Georgia State Entomol. Bull., 78, 1933; Phytopath., *29*, 1939, 12 (Abst.); Hutchins and Rue, *ibid.*, *29*, 1939, 12 (Abst.).

4. **Nanus holodisci** H. (*loc. cit.*, 127). From New Latin *Holodiscus*, generic name of ocean spray.

Common name: Ocean-spray witches'-broom virus.

Host: *ROSACEAE—Holodiscus discolor* Max., ocean spray.

Geographical distribution: United States (Oregon and Washington).

Induced disease: In ocean-spray, diseased branches form clusters of thin wiry shoots with abnormally short internodes and crowded small leaves. Laterals numerous and more than normally branched. Bronzy red color acquired early by affected foliage.

Transmission: By aphid, *Aphis spiraeae* Schout. (*APHIDIDAE*). By grafting. Not demonstrated by inoculation of expressed juice.

Literature: Zeller, Phytopath., *21*, 1931, 923–925.

5. **Nanus fragariae** H. (Holmes, *loc. cit.*, 128; *Blastogenus fragariae* McKinney, Jour. Washington Acad. Science, *34*, 1944, 151.) From New Latin *Fragaria*, generic name of strawberry.

Common name: Strawberry witches'-broom virus.

Host: *ROSACEAE—Fragaria chiloensis* Duch. var. *ananassa* Bailey, cultivated strawberry.

Geographical distribution: United States (western Oregon).

Induced disease: In strawberry, leaves numerous, light in color, with spindly petioles, margins of leaflets bent down, runners shortened, plants dwarfed; flower stalks spindly and unfruitful; root systems normal and well developed.

Transmission: By aphis, *Myzus fragaefolii* Ckll. (*APHIDIDAE*). Not demonstrated by inoculation of expressed juice.

Literature: Zeller, Phytopath., *17*, 1927, 329–335.

6. **Nanus cupuliformans** Zeller and Weaver. (Phytopath., *31*, 1941, 851.) From diminutive of Latin *cupa*, tub, and participal from Latin *formare*, to form.

Common name: Strawberry-stunt virus.

Host: *ROSACEAE—Fragaria chiloensis* Duch. var. *ananassa* Bailey, cultivated strawberry.

Geographical distribution: United States (Oregon, Washington).

Induced disease: In strawberry, little if any reduction in chlorophyll, plants erect but short; leaves at first folded, later open, dull in lustre, with papery rattle when brushed by hand, leaflets cupped or with margins turned down, midveins tortuous; petioles ½ to ⅔ normal length; fruits small, usually hard and seedy; roots normal in appearance.

Transmission: By strawberry-leaf aphid, *Capitophorus fragaefolii* (*APHIDIDAE*). By grafting. Not by inoculation of expressed juice.

7. **Nanus pruni** H. (*loc. cit.*, 128). From New Latin *Prunus*, generic name of prune, from Latin *prunus*, plum tree.

Common name: Prune-dwarf virus.

Hosts: *ROSACEAE—Prunus domestica* L., prune and plum; var. *insititia* Bailey, the Damson plum, remains symptomless. Experimentally, also *Prunus persica* (L.) Batsch, peach.

Insusceptible species: *ROSACEAE—Prunus avium* L., cherry.

Geographical distribution: United States (New York); Canada (British Columbia, Ontario).

Induced disease: In prune, leaves small, narrow, rugose, distorted, glazed. Internodes short. Some branches escape and appear normal. Blossoms numerous, mature fruits few. Pistils aborted, petals narrow and distorted. In Damson and Bradshaw plums, no obvious manifestations of disease as a result of infection.

Transmission: By budding and other forms of grafting. Not demonstrated by inoculation of expressed juice. No insect vector is known.

Literature: Berkeley, Canada, Domin. Dept. Agr., Div. of Bot. and Plant Path., Science Service, Publ. 679, 1941; Hildebrand, Phytopath., *32*, 1942, 741–751; Thomas and Hildebrand, Phytopath., *26*, 1936, 1145–1148.

8. **Nanus sacchari** H. (*loc. cit.*, 129). From New Latin *Saccharum*, generic name of sugar cane, from Latin *saccharum*, sugar.

Common name: Sugar-cane sereh-disease virus.

Host: *GRAMINEAE—Saccharum officinarum* L., sugar cane.

Geographical distribution: Java, Borneo, Sumatra, Moluccas, India, Mauritius, Australia, Fiji, Formosa, Hawaii, Ceylon.

Induced disease: In sugar cane (Cheribon variety), plant dwarfed, shoots stunted, vascular bundles colored by the presence of a red gum; adventitious roots from many or all nodes.

Transmission: Not by inoculation of expressed juice. No insect vector is known.

Thermal inactivation: In cuttings of sugar cane, at 52° C in 30 minutes to 1 hour. Infected cane cuttings survive the heat treatment required for cure through inactivation of the causative virus.

Literature: Houtman, Arch. Suikerind. Nederland.-Indië, *33*, 1925, 631–642; Lyon, Bull. Exp. Sta. Hawaiian Sugar Planters' Assoc., Bot. Ser., *3*, 1921, 1–43; Wilbrink, Arch. Suikerind. Nederland.-Indië, *31*, 1923, 1–15.

Genus V. Rimocortius *Milbrath and Zeller.*

(Phytopath., *32*, 1942, 430.)

Viruses of the Rough-Bark Group, inducing diseases principally affecting bark, less often wood, leaves, or fruit. Generic name from Latin *rima*, cleft or fissure, and *cortex*, bark.

The type species is *Rimocortius kwanzani* Milbrath and Zeller.

(NOTE: The genus *Citrivir* (first named species, *Citrivir psorosis* Fawcett, Phytopath., *31*, 1941, 357) was proposed by its author as a *genus pro tempore* with the avowed purpose of accommodating viruses causing diseases in species of the plant-host genus *Citrus*. It appears to have been implied by the term *genus pro tempore* that evidences of natural relationship, when discovered, would permit even the first-named species of this genus to be assigned elsewhere. On the assumption that a permanent genus is nothing more than a *type species* and such other species as may be added to it by one or another author, it must be felt that a *genus pro tempore*, however convenient as an expedient, cannot become a permanent genus under any circumstances, because its first-named species would appear not to be a permanent part of the genus and so intended not to be a true type-species. Without a type species there would seem to be no permanent genus concept.

The system by which the term *Citrivir* was coined (explained by its author as use of the genitive of the host-genus name, *Citris*, plus *vir*, signifying virus) seems in itself acceptable, for it is commonly agreed that a generic name may be made in an arbitrary manner. It may be noted that use of the stem of the host-genus name (*Citr-*) with connecting vowel *i* and suffix *-vir*, possibly a more orthodox procedure, would have given the same result in the present instance. The original definition of the term *Citrivir* might be thought to be repugnant as disregarding concepts of natural interspecific relationships that are essential to the spirit of binomial nomenclature. Were the genus to be regarded as permanent rather than *pro tempore*, however, the scope of the genus would come to be wholly changed by usage, when, with passage of time related species would be added to what in this case would be a type species, without regard to the unorthodox intent of the original definition but solely in accordance with similarities between viruses. A generic concept need never be accepted as rigidly defined, whether initially, as has been attempted in this case, or upon further experience, because a genus may still grow by the addition of closely allied new species beyond any limit that may be set. On this account an original, or any subsequent, definition may be regarded as subject to unlimited change so long as the type species is logically retained. The form and definition of the term *Citrivir* would not, therefore, militate against its continued use. Its avowedly temporary status alone seems decisively to do so.

The originally monotypic genus *Rimocortius*, published in the following year, was defined only by the combined generic and specific description, and was not referred to a family by its authors. The type, because at first the only species, *Rimocortius kwanzani*, is the flowering-cherry rough-bark virus. This type species might well be associated with the species *Citrivir psorosis*, citrus-psorosis virus, discussed above, both affecting bark principally, though foliage also to some extent. Although the genus *Citrivir* was named in 1941 and *Rimocortius* not until 1942, the first was intended as a temporary assemblage only, as above indicated. It would seem appropriate, therefore, to include the virus that was known temporarily as *Citrivir psorosis* in the permanent genus *Rimocortius* Milbrath and Zeller and to assign this genus to the family *Marmoraceae*.)

Key to the species of the genus **Rimocortius.**

I. Affecting cherry.
   1. *Rimocortius kwanzani.*

II. Affecting *Citrus*.
   2. *Rimocortius psorosis.*

III. Affecting pear.
   3. *Rimocortius pyri.*

1. **Rimocortius kwanzani** Milbrath and Zeller. (Phytopath., *32*, 1942, 430.) From Kwanzan, name of a variety of flowering cherry.

Common name: Flowering-cherry rough-bark virus.

Hosts: *Prunus serrulata* Lindl. var. Kwanzan, flowering cherry; *P. avium* L., Mazzard cherry.

Geographical distribution: United States (Oregon).

Induced disease: In flowering cherry, tree dwarfed, deficient in lateral branches; bark deep brown, roughened, splitting longitudinally; internodes shortened, bunching leaves; leaves arched downward; midribs of leaves split and cracked on under surface. In Mazzard cherry, no manifestation of disease, but carrier condition; budded Mazzard stock may transmit disease to healthy Kwanzan cherry cions.

Transmission: By budding, generally even if the inserted bud fails to survive.

Literature: Milbrath and Zeller, Phytopath., *32*, 1942, 428–430; Thomas, *ibid.*, *32*, 1942, 435–436.

2. **Rimocortius psorosis** (Fawcett) *comb. nov.* (*Citrivir psorosis* Fawcett, Phytopath., *31*, 1941, 357.) Specific name meaning "of the disease known as psorosis."

Common name: Citrus-psorosis virus.

Hosts: *RUTACEAE—Citrus sinensis* Osbeck, orange; *C. limonia* Osbeck, lemon; *C. maxima* Merr., grapefruit.

Geographical distribution: World-wide where citrus trees are grown.

Induced disease: In citrus, small, elongated, light colored areas or flecks in the region of small veins on young, tender foliage; leaves sometimes warped; (chlorotic?) clearing of veins, and chlorotic line patterns, sometimes concentric. Outer layers of bark scale away; depressions and deformities appear in bark and wood. Lemons, as a rule, are more tolerant than oranges and are not subject to the bark changes.

Transmission: By grafting, including root grafting and patch bark grafting. Not by inoculation of expressed juice. No insect vector is known.

Literature: Bitancourt et al., Phytopath., *33*, 1943, 865–883; Fawcett, *ibid.*, *24*, 1934, 659–668; Science, *92*, 1940, 559–561; Phytopath., *31*, 1941, 356–357; Fawcett and Bitancourt, *ibid.*, *33*, 1943, 837–864; Rhoads, *ibid.*, *32*, 1942, 410–413; Webber and Fawcett, Hilgardia, *9*, 1935, 71–109.

Strains: Three strains differing from the type have been recognized. The type, var. *vulgare* Fawcett, Phytopath., *31*, 1941, 357, causes psorosis A, the common scaly-bark type of disease, with pustular eruptions of outer layers of bark in limited areas, with or without exudation of gum; later a drab-gray, cinnamon-drab to rufus discoloration of the wood, accompanied by decline of the affected tree. Others, that contrast with the type, are:

2a. *Rimocortius psorosis* var. *anulatum* Fawcett. (Phytopath., *31*, 1941, 357.) From Latin *anulatus*, with a ring. Causing psorosis B, known from California, resembling zonate chlorosis of Brazil in effects on leaves and fruits. Psorosis B is characterized by rapid scaling of outer bark in continuous areas, progressing rapidly along one side of trunk or branch; gum exudes in advance of scaling, necrosis follows; large circular discolored and corky spots, sometimes concentric, on fruits and mature leaves; on some fruits, circular or semi-circular furrows and bumps; rapid decline of the affected tree.

2b. *Rimocortius psorosis* var. *concavum* Fawcett and Bitancourt. (Phytopath., *33*, 1943, 850.) From Latin *concavus*, concave. Causing concave-gum psorosis, characterized by concavities of various sizes on trunks and larger limbs of affected trees, often by zonate patterns on young leaves during periods of rapid growth.

2c. *Rimocortius psorosis* var. *alveatum* Fawcett and Bitancourt. (Phytopath., *33*, 1943, 854.) From Latin *alveatus*, hollowed out like a trough. Causing blind-pocket psorosis, characterized by trough-like pockets in bark and wood or by eruptive lesions.

3. **Rimocortius pyri** (Holmes) *comb. nov.* (*Marmor pyri* Holmes, Handb. Phytopath. Viruses, 1939, 76.) From New Latin *Pyrus*, generic name of pear, from Latin *pirus*, pear tree.

Common name: Pear stony-pit virus.

Host: *ROSACEAE—Pyrus communis* L., pear.

Geographical distribution: United States (Oregon, Washington, California).

Induced disease: In pear, fruit deeply pitted and deformed; bark cracked and resembling oak bark; veinlet chlorosis of some leaves, failure of lateral buds to grow, reduction of foliage. Bartlett and Comice varieties of pear appear to be tolerant, producing sound fruit from infected trees.

Transmission: By budding. Not by inoculation of expressed juice. No insect vector is known.

Literature: Kienholz, Phytopath., *29*, 1939, 260–267; *30*, 1940, 787 (Abst.).

Genus VI. Adelonosus *Brierley and Smith.*

(Phytopath., *34*, 1944, 551.)

Viruses capable of multiplying in living plants but producing no recognizable symptoms in these except on interaction with distinct viruses with which they form complexes. Transmitted by aphids, by sap, or by both means. Generic name from Greek *adelos*, invisible, and *nosos*, disease. Only one species is recognized thus far; this is the type species, *Adelonosus lilii* Brierley and Smith.

1. **Adelonosus lilii** Brierley and Smith. (Phytopath., *34*, 1944, 551.) From Latin *lilium*, lily.

Common name: Lily-symptomless virus.

Host: *LILIACEAE—Lilium longiflorum* Thunb., Easter lily.

Insusceptible species: All other tested lilies and many related plants in the same and other families (for list, see Phytopath., *34*, 1944, 549).

Geographical distribution: United States, Japan; probably coextensive with commercial culture of Easter lily.

Induced disease: In Easter lily, no obvious manifestation of disease when this virus is present alone; when together with cucumber-mosaic virus, however, the lily-symptomless virus is a determining factor in the production of necrotic-fleck disease; the lily-symptomless virus is so widely distributed in supposedly healthy stocks of the Easter lily that cucumber-mosaic virus formerly was thought to be the sole determining factor in necrotic flecking, now recognized to be caused by the virus complex lily-symptomless virus (*Adelonosus lilii*) *plus* cucumber-mosaic virus (*Marmor cucumeris*); the complex acts independently of the presence or absence of lily latent-mosaic virus (*Marmor mite*), which is often present with the essential members of the complex in flecked Easter lilies.

Transmission: By inoculation of expressed juice, with some difficulty. By aphid, *Aphis gossypii* Glov., cotton aphid (*APHIDIDAE*); preinfective period after obtaining virus, 4 to 6 days.

FAMILY III. ANNULACEAE HOLMES.

(Handb. Phytopath. Viruses, 1939, 97.)

Viruses of the Ringspot Group, causing diseases usually characterized by necrotic or chlorotic spotting with concentric-ring lesions and eventual recovery from obvious disease with non-sterile immunity. Hosts, higher plants; vectors unknown. There is a single genus.

Genus I. **Annulus** *Holmes.*

(*Loc. cit.*, 97.)

Characters those of the family. Generic name from Latin *annulus*, a ring.

The type species is *Annulus tabaci* Holmes.

Key to the species of genus **Annulus.**

I. Found occurring naturally in the Western Hemisphere.
  A. In tobacco.
    1. *Annulus tabaci.*
    2. *Annulus zonatus.*
    3. *Annulus orae.*
    4. *Annulus apertus.*
  B. In potato.
    5. *Annulus dubius.*
  C. In delphinium.
    6. *Annulus delphinii.*
II. Old World species.
    7. *Annulus bergerac.*

1. **Annulus tabaci** Holmes. (Handb. Phytopath. Viruses, 1939, 98; *Marmor anularium* McKinney, Jour. Washington Acad. Sci., *34*, 1944, 327.) From New Latin *Tabacum*, early generic name for tobacco.

Common names: Tobacco-ringspot virus, green ringspot virus, yellow ringspot virus, ring spot No. 1 virus.

Hosts: *SOLANACEAE—Nicotiana tabacum* L., *Petunia violacea* Lindl., *Solanum tuberosum* L. *CUCURBITACEAE—Cucumis sativus* L. Experimentally this virus has been found capable of infecting many species of plants in a large number of families; these include all tested species of the *SOLANACEAE, SCROPHULARIACEAE, COMPOSITAE,* and *CUCURBITACEAE.* Many species of the *LEGUMINOSAE* are susceptible and one, *Vigna sinensis* (L.) Endl., is used as an indicator plant for quantitative measurement because it displays conspicuous reddish-brown necrotic lesions around points of initial infection.

Geographical distribution: United States.

Induced disease: In tobacco, necrotic ring-like primary lesions, followed by secondary necrotic rings on younger leaves. Subsequently, affected plants recover. After recovery from obvious disease, virus content of plants is only 10 to 20 per cent of that of recently infected plants. Some varieties may show mosaic-like patterns in young leaves at 16°C.

Transmission: By inoculation of expressed juices. Through about 20 per cent of seeds from diseased petunia plants. Not by dodder, *Cuscuta campestris* Yuncker (*CONVOLVULACEAE*).

Serological relationships: Induces the formation of specific precipitating antibodies when injected into bloodstream of rabbit.

Immunological relationships: Recovered tobacco plants are not susceptible to reinfection with this virus but are readily infected with *Annulus zonatus* or *A. orae.* This virus produces primary lesions on

leaves of plants immune to reinfection with *A. bergerac*.

Thermal inactivation: At 68° C in 10 minutes.

Filterability: Passes V, N, and perhaps W Berkefeld filters.

Other properties: Particle size estimated by filtration experiments as about 19 millimicrons. Sedimentation constant, $S_{20°} = 115 \times 10^{-13}$ cm. sec.$^{-1}$ dyne^{-1}. Infective in dilutions of 10^{-7} after purification. Inactivated in 1 hour below pH 3 or above pH 10.8. Recovered plants of tobacco contain 0.002 mg of virus per gram, recently infected plants about 6 times as much. Optimum conditions for retaining infectivity of stored virus include suspension in 0.01 M phosphate buffer at pH 7 and storage at 4° C.

Literature: Fenne, Phytopath., *21*, 1931, 891–899; Fromme et al., *ibid.*, *17*, 1927, 321–328; Henderson, *ibid.*, *21*, 1931, 225–229; Henderson and Wingard, Jour. Agr. Res., *43*, 1931, 191–207; Price, Contrib. Boyce Thompson Inst., *4*, 1932, 359–403; Phytopath., *26*, 1936, 503–529; Am. Jour. Bot., *27*, 1940, 530–541; Am. Naturalist, *74*, 1940, 117–128; Priode, Am. Jour. Bot., *15*, 1928, 88–93; Stanley, Jour. Biol. Chem., *129*, 1939, 405–428, 429–436; Stanley and Wyckoff, Science, *85*, 1937, 181–183; Valleau, Kentucky Agr. Exp. Sta., Bull. 327, 1932; Wingard, Jour. Agr. Res., *37*, 1928, 127–153; Woods, Contrib. Boyce Thompson Inst., *5*, 1933, 419–434.

Strains: A number of distinctive strains have been collected in nature and studied experimentally. The following have been given varietal names to distinguish them from the type, var. *virginiensis* H., *loc. cit.*, 98:

1a. *Annulus tabaci* var. *kentuckiensis* H. (*loc. cit.*, 99). Differing from the typical strain in producing less necrosis and less stunting in tobacco. (Price, Phytopath., *26*, 1936, 665–675; Valleau, Kentucky Agr. Exp. Sta., Bull. 327, 1932.)

1b. *Annulus tabaci* var. *auratus* H. (*loc. cit.*, 100). Secondary lesions in tobacco at first yellow spots or rings, becoming necrotic subsequently. Recovery less complete than with type, abnormal yellowing of old leaves tending to persist. (Chester, Phytopath., *25*, 1935, 686–701; Price, Phytopath., *26*, 1936, 665–675; Valleau, Kentucky Agr. Exp. Sta., Bull. 327, 1932; Phytopath., *29*, 1939, 549–551.)

2. **Annulus zonatus** H. (*loc. cit.*, 101). From Latin *zonatus*, zonate.

Common names: Tomato-ringspot virus, ring spot No. 2 virus.

Hosts: *SOLANACEAE—Nicotiana tabacum* L., tobacco. Experimentally this virus has been found to infect many species of plants in a large number of families.

Geographical distribution: United States.

Induced disease: In tobacco, zonate necrotic primary lesions and, temporarily, secondary lesions of the same type; recovery with specific, non-sterile immunity. In tomato, systemic infection, yellowish-green or necrotic ring-like lesions; stunting.

Transmission: By inoculation of expressed juice.

Immunological relationships: Recovered plants are immune to reinfection but are still susceptible to *Annulus tabaci*, *A. bergerac*, and several mosaic-type viruses that have been tested.

Thermal inactivation: At 55 to 60° C in 10 minutes.

Filterability: Passes Gradocol membrane 100 millimicrons in average pore diameter. Particle size estimated as 50 millimicrons or less.

Literature: Price, Phytopath., *26*, 1936 665–675; Am. Jour. Bot., *27*, 1940, 530–541.

3. **Annulus orae** H. (Holmes, *loc. cit.*, 103; *Tractus orae* Valleau, Phytopath., *30*, 1940, 826.) From Latin *ora*, edge, in reference to occurrence of induced disease near edge of tobacco fields.

Common name: Tobacco-streak virus.

Hosts: *SOLANACEAE—Nicotiana tabacum* L., tobacco. Experimentally, a

number of other solanaceous plants have been reported as susceptible, but not *Capsicum frutescens* L., pepper; *Lycopersicon esculentum* Mill., tomato; *Solanum melongena* L., eggplant; or *S. tuberosum* L., potato.

Geographical distribution: United States.

Induced disease: In tobacco, local and systemic necrosis in 3 days, with irregular spot, line, and ring-like lesions, followed by recovery from necrotic manifestations of disease. Recovered leaves may show a mild mottling and regularly contain virus; reinoculation does not induce formation of necrotic lesions in them.

Transmission: By inoculation of expressed juice. Not through seeds from diseased plants.

Immunological relationships: No cross-protection with respect to *A. tabaci*, and several viruses of the mosaic group.

Thermal inactivation: At 53° C in 10 minutes.

Literature: Johnson, Phytopath., *26*, 1936, 285–292; Trans. Wisconsin Acad. Sciences, Arts and Letters, *30*, 1937, 27–34.

4. **Annulus apertus** *spec. nov.* From Latin *apertus*, frank.

Common name: Broad-ringspot virus.

Hosts: *SOLANACEAE—Nicotiana tabacum* L., tobacco. Experimentally also to many species in this and other families.

Insusceptible species: *CHENOPODIACEAE—Beta vulgaris* L. *CUCURBITACEAE—Citrullus vulgaris* Schrad. *LEGUMINOSAE—Medicago sativa* L., *Melilotus alba* Desr.

Geographical distribution: United States (Wisconsin).

Induced disease: In tobacco, indistinct yellow-spot primary lesions, becoming chlorotic or necrotic rings with concentric markings; small chlorotic rings, sometimes concentric, or fine brown necrotic rings as secondary lesions; young leaves puckered at first, somewhat malformed.

Transmission: By inoculation of expressed juice.

Immunological relationships: Protects against reinfection with homologous virus but leaves host susceptible to infection by *Annulus tabaci*, *A. zonatus*, and some mosaic-type viruses.

Literature: Johnson and Fulton, Phytopath., *32*, 1942, 605–612.

5. **Annulus dubius** (Holmes) *comb.nov.* (*Marmor dubium* H., *loc. cit.*, 42.) From Latin *dubius*, uncertain, in reference to a common name, potato virus X, often used to designate this virus.

Common name: Potato-mottle virus (strains of this virus have been studied at various times under the names potato latent virus, potato virus X, potato-anecrosis virus, virulent latent virus, simple mosaic virus, healthy potato virus, Hyoscyamus IV virus, President streak virus, potato foliar-necrosis virus, potato acronecrotic streak virus, Up-to-Date streak virus, potato viruses B and D, Solanum viruses 1, 4, and 6.)

Hosts: *SOLANACEAE—Solanum tuberosum* L., potato; *Lycopersicon esculentum* Mill., tomato. Experimentally, also *SOLANACEAE—Capsicum frutescens* L., pepper; *Datura stramonium* L., Jimson weed; *Hyoscyamus niger* L., henbane; *Nicotiana tabacum* L., tobacco; *Physalis alkekengi* L.; *Solanum dulcamara* L., bittersweet; *S. nigrum* L., black nightshade. *AMARANTHACEAE—Amaranthus retroflexus* L. *COMPOSITAE—Chrysanthemum morifolium* Ram. *SCROPHULARIACEAE—Veronica* sp., common speedwell.

Geographical distribution: Widespread throughout the world; present in all known stocks of tubers of some potato varieties in the United States.

Induced disease: In potato, usually no chlorotic mottling, sometimes a little; intracellular inclusions of the vacuolated, granular type; some varieties that are virtually immune in the field owe their tendency to localize the virus in necrotic primary lesions or in top-necrosis of first systemically infected plants to a dom-

inant allele of a gene *nx*, which characterizes plants showing a mosaic of some degree of intensity on infection with this virus; the variety known as S41956 is immune to all tested strains of the virus and possesses two dominant genes both required for resistance. In tomato, systemic mild chlorotic mottling; if a strain of tobacco-mosaic virus is also present, a severe systemic necrosis, known as double-virus streak, is induced.

Transmission: By inoculation of expressed juice. Experimentally, by leaf contacts mainly under the influence of wind. No insect vector is known. Not transmitted through true seeds of the potato.

Serological relationships: Cross precipitin reactions between constituent strains of this virus. No cross reaction with potato aucuba-mosaic, potato mild-mosaic, potato-veinbanding, tobacco-mosaic, tobacco-etch, tobacco-ringspot or pea-mosaic virus. Antisera prepared by injecting rabbits intravenously with virus inactivated by nitrous acid, like those prepared with active virus, fix complement and flocculate with virus suspensions (though not with juice of healthy host plants); they are also effective in neutralizing the virus.

Immunological relationships: Tobacco and *Datura* plants infected by the type strain of this virus become immune to the more severe potato-ringspot strain. No protection against the severe strain is afforded by previous infection with tobacco-mosaic, tobacco-ringspot, tomato spotted-wilt, or cucumber-mosaic virus.

Thermal inactivation: At 70° C. in 10 minutes.

Filterability: Passes Pasteur-Chamberland L_1, L_3, and L_5 filters.

Other properties: Digested by 0.02 per cent solution of pepsin in 3 hours at pH 4, at 38° C. Digested also by trypsin. Inactivated by papaine and cyanide, but by neither separately. Isoelectric point near pH 4. Dilute solutions show anisotropy of flow. Concentrated solutions are spontaneously birefringent. Properties of the type strain have been less studied than those of the potato-ringspot strain of this virus.

Literature: Bawden, Proc. Roy. Soc. London, Ser. B, *116*, 1934, 375–395; Bawden and Pirie, Brit. Jour. Exp. Path., *17*, 1936, 64–74; Bawden et al., *ibid.*, *17*, 1936, 204–207; Blodgett, Phytopath., *17*, 1927, 775–782; Böhme, Phytopath. Ztschr., *6*, 1933, 517–524; Cadman, Jour. Genetics, *44*, 1942, 33–52; Chester, Phytopath., *27*, 1937, 903–912; Clinch, Sci. Proc. Roy. Dublin Soc., *23*, 1942, 18–34; Johnson, Wisconsin Agr. Exp. Sta., Res. Bull. 63, 1925; Koch, Phytopath., *23*, 1933, 319–342; Köhler, Phytopath. Ztschr., *5*, 1933, 567–591; *7*, 1934, 1–30; Loughnane and Murphy, Nature, *141*, 1938, 120; van der Meer, Cent. f. Bakt., II Abt., *87*, 1932, 240–262; Salaman, Nature, *131*, 1933, 468; Schultz et al., Phytopath., *27*, 1937, 190–197; *30*, 1940, 944–951; Spooner and Bawden, Brit. Jour. Exp. Path., *16*, 1935, 218–230; Stevenson et al., Phytopath., *29*, 1939, 362–365.

Strains: Several variants of potato-mottle virus, differing from the type, var. *vulgaris* H. (*loc. cit.*, 42), have been recognized as distinctive varieties under the following names:

5a. *Annulus dubius* var. *annulus* H. (*loc. cit.*, 44). From Latin *annulus*, ring.

Common name: Ringspot strain of potato-mottle virus. Necrotic primary and secondary ring-like lesions in experimentally infected tobacco plants. Indistinguishable from type strain by ordinary precipitin test, but distinguishable when appropriately absorbed sera are used. This strain has been more frequently studied than the type. Juice of infected tobacco plants contains about 0.02 to 0.10 mg of virus per ml. Sedimentation constants, $S_{20^\circ} = 113 \times 10^{-13}$ and 131×10^{-13} cm. sec.$^{-1}$ dyne^{-1}. Dissymmetry constant 2.78. Molecular weight 26×10^6. Particle size estimated to be 433 by 9.8 millimicrons, 43.9 times as long as wide. Isoelectric point near pH 4. Stable between pH 4 and pH 9.5. Concentrated solutions are spontaneously birefringent. Dilute solutions show

anisotropy of flow. Destroyed by drying. Inactivated by papaine and cyanide, but by neither separately. Digested by 0.02 per cent solution of pepsin in 3 hours at pH 4, at 38° C. Digested also by trypsin. About 6 per cent of the purified virus is reported to be a pentose nucleic acid, but the carbohydrate to phosphorus ratio is about twice that for yeast nucleic acid. Guanine and pentose present. Analysis of sedimented virus, carbon 47.7 to 49.5 per cent, hydrogen 6.8 to 7.7 per cent, nitrogen 14.6 to 17.0 per cent, phosphorus 0.4 to 0.7 per cent, sulfur 1.1 per cent, carbohydrate 2.5 to 4.3 per cent, ash 2.0 to 2.5 per cent. Reduction of carbohydrate content of sample to 2.5 per cent does not reduce activity of virus; further reduction inactivates. (Ainsworth, Ann. Appl. Biol., *21*, 1934, 581–587; Bawden, Brit. Jour. Exp. Path., *16*, 1935, 435–443; Bawden and Pirie, *ibid.*, *19*, 1938, 66–82; Birkeland, Bot. Gaz., *95*, 1934, 419–436; Chester, Phytopath., *26*, 1936, 778–785; Johnson, Wisconsin Agr. Exp. Sta., Res. Bull. *76*, 1927; Loring, Jour. Biol. Chem., *126*, 1938, 455–478; Loring and Wyckoff, *ibid.*, *121*, 1937, 225–230.)

5b. *Annulus dubius* var. *flavus* H. (*loc. cit.*, 46). From Latin *flavus*, yellow. Common name: Yellow-mottle strain of potato-mottle virus. Differing from the type by imparting a yellow cast to foliage of infected potatoes. (Putnam, Canad. Jour. Res., Sec. C, *15*, 1937, 87–107.)

5c. *Annulus dubius* var. *obscurus* H. (*loc. cit.*, 46). From Latin *obscurus*, obscure. Common name: Masked-mottle strain of potato-mottle virus. Differing from the type by systemically infecting potato, tobacco, and Jimson weed without symptoms under ordinary experimental conditions; in pepper, however, systemic necrosis is induced, as by all known strains. (Chester, Phytopath., *26*, 1936, 778–785.)

6. **Annulus delphinii** *spec. nov.* From New Latin *Delphinium*, generic name of host.

Common names: Delphinium-ringspot virus, perennial-delphinium ringspot virus.

Hosts: *RANUNCULACEAE—Delphinium* sp., perennial delphiniums. Experimentally, also to *CHENOPODIACEAE—Beta vulgaris* L. *CUCURBITACEAE—Cucumis sativus* L., cucumber. *MALVACEAE — Gossypium hirsutum* L. *RANUNCULACEAE—Ranunculus asiaticus* L. (symptomless carrier). *SOLANACEAE—Datura stramonium* L., *Nicotiana alata* Link and Otto, *N. glutinosa* L., *N. rustica* L., *N. tabacum* L., *Petunia hybrida* Vilm.

Geographical distribution: United States (California).

Induced disease: In perennial delphiniums, faint chlorotic rings with green or yellow centers on young leaves; irregular chlorotic spots, yellow bands, or irregular chlorotic rings on mature leaves.

Transmission: By inoculation of expressed juice in the presence of finely powdered carborundum.

Thermal inactivation: At 65° C in 10 minutes.

Literature: Severin and Dickson, Hilgardia, *14*, 1942, 465–490.

7. **Annulus bergerac** H. (*loc. cit.*, 102). From Bergerac, a town in southwest France.

Common name: Bergerac-ringspot virus.

Hosts: *SOLANACEAE—Nicotiana tabacum* L., tobacco. Experimentally, this virus has been transferred to several other solanaceous plants and to *Phaseolus vulgaris* L., bean, in the family *LEGUMINOSAE*.

Geographical distribution: France.

Induced disease: In tobacco, thin necrotic-ring primary lesions, followed by

systemic mottling with some chlorotic rings on the dark green islands. Later, complete recovery occurs, with non-sterile immunity.

Transmission: By inoculation of expressed juice.

Immunological relationships: Recovered plants are susceptible to infection by *Annulus tabaci* and *A. zonatus*.

Thermal inactivation: At 80° C in 10 minutes.

Literature: Smith, A textbook of plant virus diseases, P. Blakiston's Son and Co., Inc., Philadelphia, 1937, 285–289.

FAMILY IV. RUGACEAE HOLMES.

(Handb. Phytopath. Viruses, 1939, 114)

Viruses of the Leaf-Curl Group, causing diseases characterized by suddenly arrested development of invaded tissues, resulting in leaf curl, enations, and other deformities. Vectors, typically white-flies (*ALEYRODIDAE*). There is a single genus.

Genus I. Ruga *Holmes.*

(*Loc. cit.*, 114.)

Characters those of the family. Generic name from Latin *ruga*, a wrinkle. The type species is *Ruga tabaci* Holmes.

Key to the species of genus **Ruga.**

I. Infecting tobacco.
  1. *Ruga tabaci.*

II. Infecting cotton.
  2. *Ruga gossypii.*

III. Infecting cassava (*Manihot*).
  3. *Ruga bemisiae.*

IV. Infecting sugar-beet.
  4. *Ruga verrucosans.*

1. **Ruga tabaci** Holmes. (Handb. Phytopath. Viruses, 1939, 115.) From New Latin *Tabacum*, former generic name of tobacco.

Common names: Tobacco leaf-curl virus, kroepoek virus, curl-disease virus, crinkle-disease virus.

Hosts: *SOLANACEAE—Nicotiana tabacum* L., tobacco. *COMPOSITAE—Vernonia iodocalyx, V. cineria, Ageratum conyzoides* L., *Synedrella nodiflora* Gaertn. Experimentally, also other solanaceous plants.

Insusceptible species: *MALVACEAE—Gossypium hirsutum* L., cotton.

Geographical distribution: Tanganyika, Southern Rhodesia, Southern Nigeria, Nyasaland, India, Sumatra, Formosa.

Induced disease: In tobacco, leaves curled and crinkled, with occasional leafy outgrowths or enations. Veins greened and thickened. No chlorosis nor necrosis. Plant stunted.

Transmission: By white-fly, *Bemisia gossypiperda* Misra and Lamba (*ALEYRODIDAE*). By grafting. Not by inoculation of expressed juice.

Literature: Kerling, Phytopath., *23*, 1933, 175–190; Mathur, Indian Jour. Agr. Sci., *3*, 1933, 89–96; Matsumoto and Tateoko, Trans. Nat. Hist. Soc. Formosa, *30*, 1940, 31–33; Pal and Tandon, Indian Jour. Agr. Sci., *7*, 1937, 363–393; Pruthi and Samuel, *ibid.*, *7*, 1937, 659–670; Storey, Nature, *128*, 1931, 187–188; East African Agr. Jour., *1*, 1935, 148–153; Thung, Meded. Proefsta. Vorstenl. Tabak Java, *72*, 1932; *78*, 1934.

2. **Ruga gossypii** H. (*loc. cit.*, 116). From Latin *gossypium*, cotton.

Common names: Cotton leaf-curl virus, cotton leaf-crinkle virus.

Hosts: *MALVACEAE—Gossypium hirsutum* L., cotton; *G. peruvianum* Cav.; *G. vitifolium* Lam.; *Hibiscus cannabinus* L.; *H. esculentus* L.; *H. sabdariffa* L.; *Althaea rosea* Cav., hollyhock; Sakel (hybrid) cotton.

Geographical distribution: The Sudan and Nigeria, in Africa.

Induced disease: In cotton, clearing of veins, blistering and pale spotting of leaves; leaves puckered at edge and unsymmetrical. Internodes shortened, producing bunchy growth.

Transmission: By white-fly, *Bemisia gossypiperda* Misra and Lamba (*ALEY-

RODIDAE). Not through egg of insect vector. Not by inoculation of expressed juice. Not through soil. Not through seeds from diseased plants.

Literature: Bailey, Empire Cotton Growing Rev., *11*, 1934, 280; Kirkpatrick, Bull. Entom. Res., *21*, 1930, 127–137; *22*, 1931, 323–363.

3. **Ruga bemisiae** H. (Holmes, *loc. cit.*, 117; *Ochrosticta bemisiae* McKinney, Jour. Washington Acad. Sci., *34*, 1944, 149.) From New Latin *Bemisia*, generic name of insect vector.

Common names: Cassava-mosaic virus, cassava Kräuselkrankheit virus.

Hosts: *EUPHORBIACEAE—Manihot utilissima* Pohl, cassava; *M. palmata* Muell.; *M. dulcis*.

Geographical distribution: Gold Coast, Belgian Congo, French Cameroons, Rhodesia, Liberia, Madagascar, probably throughout Africa and adjacent islands; Java.

Induced disease: In *Manihot utilissima*, leaves unsymmetrical, curled, distorted, mottled; internodes shortened, plants stunted. Axillary buds produce an extra number of side branches.

Transmission: By white-flies (*ALEYRODIDAE*), *Bemisia nigeriensis* Corb., in Southern Nigeria, and *B. gossypiperda* Misra and Lamba, in Belgian Congo and Tanganyika. White-flies infect only young leaves. Not by needle-puncture, rubbing, or hypodermic-needle injection of juice expressed from diseased plants.

Literature: Dade, Yearbk. Dept. Agr. Gold Coast, 1930, 245; Dufrénoy and Hedin, Rev. Bot. Appl., *9*, 1929, 361–365; Golding, Trop. Agric., Trinidad, *13*, 1936, 182–186; Kufferath and Ghesquière, Compt. rend. Soc. Biol. Belge, *109*, 1932, 1146; Lefevre, Bull. Agr. Congo Belge, *26*, 1935, 442; McKinney, Jour. Agr. Res., *39*, 1929, 557–578; Muller, Bull. Inst. Plantenziekt., *24*, 1931, 1–17; Pascalet, Agron. Colon., *21*, 1932, 117; Staner, Bull. Agr. Congo Belge, *22*, 1931, 75; Storey, East Afr. Jour., *2*, 1936, 34–39; Storey and Nichols, Ann. Appl. Biol., *25*, 1938, 790–806; Zimmermann, Pflanzer, *2*, 1906, 145.

4. **Ruga verrucosans** Carsner and Bennett. (*Chlorogenus eutetticola* (in error for *eutettigicola*, from New Latin *Eutettix*, genus name of a vector, and Latin *-cola*, dweller in or inhabitant of) Holmes, 1939, *loc. cit.*, 11; Carsner and Bennett, Science *98*, 1943, 386.) From Latin, meaning: causing rough swellings.

Common name: Sugar-beet curly-top virus.

Hosts: Very wide range in many families of dicotyledonous plants. Among the horticulturally important host plants are the sugar beet (*Beta vulgaris* L., *CHENOPODIACEAE*); bean (*Phaseolus vulgaris* L., *LEGUMINOSAE*); squash (*Cucurbita* species, *CUCURBITACEAE*); and tomato (*Lycopersicon esculentum* Mill., *SOLANACEAE*).

Geographical distribution: Western North America; in Argentina a strain of virus thought to belong here has been reported but has not yet been fully described.

Induced disease: In beet, clearing of veins, leaf curling, sharp protuberances from veins on lower surface of leaves, increase in number of rootlets, phloem degeneration followed by formation of supernumerary sieve tubes, retardation of growth. In tomato, (western yellow blight or tomato yellows), phloem degeneration followed by formation of supernumerary sieve tubes, retardation of growth, dropping of flowers and buds, rolling, yellowing and thickening of leaves, root decay, usually followed by death, sometimes by recovery. Occasionally there is relapse after recovery. In cucurbitaceous plants, stunting, bending upward of tip of runner, yellowing of old leaves, abnormally deep green in tip leaves and stem; Marblehead squash is tolerant, showing only mild witches' broom formation and phyllody. In bean, infected when young, thickening and downward curling of first trifoliate leaf, which becomes brittle and will break easily from the stem; leaves become chlorotic, plant stops growing and usually dies soon; older plants are also susceptible to infection; they may survive until

the end of the season, showing puckering and downward curling of leaves at the top of the plant, reduction in size of new leaves, and shortened internodes, or they may gradually become chlorotic and die.

Transmission: By leafhopper, *Eutettix tenellus* (Baker) (*CICADELLIDAE*) with 4 to 12 hour preinfective period. Through dodder, *Cuscuta campestris* Yuncker (*CONVOLVULACEAE*). Not, with any regularity at least, by mechanical inoculation of expressed juice. Not through seeds of diseased plants to seedlings germinating from them. The leafhopper, *Agalliana ensigera* Oman (*CICADELLIDAE*), is said to transmit a South American strain of sugar-beet curly-top virus, but evidence for identity of the virus has not yet been reported in detail.

Thermal inactivation: At 75° to 80° C in 10 minutes.

Filterability: Passes Berkefeld V, N, and W, Mandler medium and fine, and Chamberland L_1, L_3, L_5, L_7, L_9, L_{11} and L_{13} filters.

Other properties: Withstands alcohol and acetone treatments. A pH of 2.9 or lower inactivates, but an alkaline reaction as high as pH 9.1 does not inactivate, in 2 hours. Virus active after at least 8 years in tissues of thoroughly dried young sugar-beet plants, 6 months in dried leafhoppers, and 10 months in dried phloem exudate.

Strains: In general it has proved possible to modify strains by host passage, some hosts like *Chenopodium murale* L. appearing to select less virulent strains, others like *Stellaria media* (L.) Cyr. reversing this selection and restoring virulence.

Literature: Bennett, Jour. Agr. Res., *48*, 1934, 665–701; *50*, 1935, 211–241; *56*, 1938, 31–52; Phytopath., *32*, 1942, 826–827; Carsner, Phytopath., *15*, 1925, 745–757; U. S. Dept. Agr., Tech. Bull. 360, 1933; Jour. Agr. Res., *33*, 1926, 345–348; Dana, Phytopath., *28*, 1938, 649–656; Fawcett, Revista Industrial y Agrícola de Tucumán, *16*, 1925, 39–46; Fife, Phytopath., *30*, 1940, 433–437; Giddings, Phytopath., *27*, 1937, 773–779; Jour. Agr. Res., *56*, 1938, 883–894; Lackey, Jour. Agr. Res., *55*, 1937, 453–460; Lesley and Wallace, Phytopath., *28*, 1938, 548–553; Murphy, *ibid.*, *30*, 1940, 779–784; Severin, Hilgardia, *3*, 1929, 595–636; Severin and Freitag, *ibid.*, *8*, 1933, 1–48; Severin and Henderson, Hilgardia, *3*, 1928, 339–393; Severin and Swezy, Phytopath., *18*, 1928, 681–690; Shaw, U. S. Dept. Agr., Bull. 181, 1910.

FAMILY V. SAVOIACEAE HOLMES.

(Handb. Phytopath. Viruses, 1939, 131.)

Viruses of the Savoy-Disease Group, causing diseases characterized mainly by crinkling of foliage. Vectors, true bugs (*PIESMIDAE* and *MIRIDAE*). There is a single genus.

Genus I. **Savoia** *Holmes.*

(*Loc. cit.*, 131.)

Characters those of the family. Generic name from French *chou de Savoie*, cabbage of Savoy, a cabbage with wrinkled and curled leaves.

The type species is *Savoia betae* Holmes.

Key to the species of genus **Savoia.**

I. Infecting beet.
- 1. *Savoia betae.*
- 2. *Savoia piesmae.*

II. Infecting rape and rutabaga.
- 3. *Savoia napi.*

1. **Savoia betae** Holmes. (Handb. Phytopath. Viruses, 1939, 132.) From Latin *beta*, beet.

Common names: Beet-Kräuselkrankheit virus, sugar-beet leaf-curl virus, sugar-beet leaf-crinkle virus, Kopfsalat virus.

Host: *CHENOPODIACEAE—Beta vulgaris* L., beet.

Geographical distribution: Germany, Poland.

Induced disease: In beet, veins of leaves swollen, retarded in growth, causing crinkling. New leaves remain small and incurved, forming a compact head. Old leaves die; plant succumbs before harvest time. Prepatent period in plant, 3 to 9 weeks.

Transmission: By tingid bug, *Piesma quadrata* Fieb. (*PIESMIDAE*). Not by inoculation of expressed juice.

Literature: Wille, Arb. Biol. Reichsanst. Land- u. Forstw., *16*, 1928, 115–167.

2. **Savoia piesmae** H. (*loc. cit.*, 132). From New Latin *Piesma*, generic name of insect vector.

Common name: Beet-savoy virus.

Host: *CHENOPODIACEAE—Beta vulgaris* L., beet.

Geographical distribution: United States (Michigan, Ohio, Minnesota, Nebraska, South Dakota, Colorado, Wyoming) and Canada.

Induced disease: In beet, leaves dwarfed, curled down, small veins thickened. Phloem necrosis in roots. Prodromal period in plant, 3 to 4 weeks.

Transmission: By tingid bug, *Piesma cinerea* (*PIESMIDAE*). Not by inoculation of expressed juice.

Literature: Coons et al., Phytopath., *27*, 1937, 125 (Abst.); Hildebrand and Koch, *ibid.*, *32*, 1942, 328–331.

3. **Savoia napi** H. (*loc. cit.*, 133). From New Latin *Napus*, former generic name of rape, *Brassica napus* L.

Common name: Rape-savoy virus.

Hosts: *CRUCIFERAE—Brassica napus* L., rape; *B. napobrassica* Mill., rutabaga.

Geographical distribution: Germany.

Induced disease: In rape, twisting and crinkling of young leaves; premature death of old leaves and of plants; in surviving plants, inhibition of growth in spring. In rutabaga, mottling and crinkling of leaves, with formation of fissures at leaf edges. Plants rarely killed.

Transmission: By inoculation of expressed juice. By the tarnished plant bug, *Lygus pratensis* Linn. (*MIRIDAE*). The insect vector retains this virus during intervals between crops.

Literature: Kaufmann, Arb. Biol. Reichsanst. Land- u. Forstw., *21*, 1936, 605–623; Mitteil. Landwirtsch., *37*, 1936; Pape, Deutsch. Landwirtsch. Presse, *26*, 1935.

FAMILY VI. LETHACEAE HOLMES.

(Handb. Phytopath. Viruses, 1939, 135.)

Virus strains of the Spotted-Wilt Group, causing diseases characterized by bronzing of foliage, streaking of stems, blighting of tips, necrotic spotting of foliage. Hosts, higher plants; vectors, thrips (*THRIPIDAE*). There is a single genus.

Genus I. **Lethum** *Holmes.*

(*Loc. cit.*, 135.)

Characters those of the family. Generic name from Latin *lethum*, death. At present there is but one known species, though this is reported to be nearly world-wide in distribution. In some areas it may have been confused with entities needing separate recognition.

The type species is *Lethum australiense* Holmes.

1. **Lethum australiense** Holmes (*loc. cit.*, 136). From Australia, where virus was first described.

Common names: Tomato spotted-wilt virus, kromnek or Kat River disease virus. Also, pineapple yellow-spot or side-rot virus (according to Sakimura, Phytopath., *30*, 1940, 281–299).

Hosts: Very numerous species in many families of higher plants. Among those most often noted are: *SOLANACEAE*—*Lycopersicon esculentum* Mill., tomato; *Nicotiana tabacum* L., tobacco; *Solanum tuberosum* L., potato. *COMPOSITAE*—*Lactuca sativa* L., lettuce. *LEGUMINOSAE*—*Pisum sativum* L., pea. *BROMELIACEAE*—*Ananas comosus* Merr., pineapple.

Geographical distribution: Australia, British Isles, United States, South Africa Hawaii, New Zealand, Europe, China, South America.

Induced disease: In tomato, bronze ring-like secondary lesions, plant stunted, some necrosis; later yellowish mosaic with some leaf distortion. Fruit frequently marked with concentric rings of pale red, yellow, or white. In tobacco, primary necrotic lesions followed by systemic necrosis, with stem streak, crookneck, often stunting with subsequent wilting and death, sometimes temporary recovery followed by recurrence of systemic necrosis. In lettuce, plant yellowed, retarded in growth; brown blemishes in central leaves, affected spots dying, becoming like parchment but with brown margins. Axillary shoots may show chlorotic mottling. In pea, purplish necrotic streaks on stem; at first, leaves mottled; later, necrotic spots damage foliage; pods show circular necrotic spots or wavy lines, or, if severely affected, may collapse; seeds may show necrotic lesions. In potato, zonate necrotic spots on upper leaves, necrotic streaks on stems; stems collapse at top; plant is stunted, yield of tubers small. In pineapple, at first an initial spot or primary lesion ⅛ to ½ inch in diameter, raised, yellowish, on upper surface of young leaf; later chlorotic spotting of young leaves, crook-neck because of necrotic foci in stems and fruits (side rot); plant may die.

Transmission: By inoculation of expressed juice; the addition of fine carborundum powder to inoculum facilitates transmission by rubbing methods. By thrips, *Frankliniella lycopersici* Andrewartha (formerly identified as *F. insularis* Franklin), *F. occidentalis* Perg., *F. moultoni* Hood. and *F. schultzei* (Trybom) (*THRIPIDAE*). Also by *Thrips tabaci* Lind. (*THRIPIDAE*). In *F. lycopersici*, thrips must pick up virus while still a nymph; virus persists through pupation and emergence as adult; preinfective period in vector, 5 to 9 days. Virus is not transmitted through eggs of

infective thrips. Probably not through seeds of infected plants. Not through soil.

Immunological relationships: Infects tobacco plants previously infected with tobacco-mosaic, potato-mottle, tobacco-ringspot, and tomato-ringspot viruses.

Thermal inactivation: At 42° C in 10 minutes.

Filterability: Passes Gradocol membrane of 0.45 micron pore diameter.

Other properties: Virus readily inactivated by desiccation or by action of oxidizing agents; activity prolonged by presence of sodium sulfite, cystein, or by low temperatures. Unstable at pH values below 6 and above 9.

Literature: Ainsworth et al., Ann. Appl. Biol., *21*, 1934, 566–580; Andrewartha, Trans. Roy. Soc. of So. Australia, *61*, 1937, 163–165; Bald and Samuel, *ibid.*, *21*, 1934, 179–190; Berkeley Scientific Agr., *15*, 1935, 387–392; Best Austral. Chem. Inst. Jour. and Proc., *4*, 1937, 375–392; Best and Samuel, Ann. Appl. Biol., *23*, 1936, 509–537; 759–780; Carter, Phytopath., *29*, 1939, 285–287; Lewcock, Queensland Agr. Jour., *48*, 1937, 665–672; Linford, *ibid.*, *22*, 1932, 301–324; Magee, Agr. Gaz. of New South Wales, *47*, 1936, 99–100, 118; McWhorter and Milbrath, Phytopath., *25*, 1935, 897–898 (Abst.); Oregon Agr. Exp. Sta., Circ. *128*, 1938; Milbrath, Phytopath., *29*, 1939, 156–168; Moore, Nature, *147*, 1941, 480–481; Moore and Anderssen, Union of So. Africa, Dept. Agr., Science Bull. 182, 1939; Parris, Phytopath., *30*, 1940, 299–312; Rawlins and Tompkins, *ibid.*, *26*, 1936, 578–587; Sakimura, *ibid.*, *30*, 1940, 281–299; Samuel and Bald, Ann. Appl. Biol., *20*, 1933, 70–99; Jour. Agr. So. Australia, *37*, 1933, 190–195; Samuel et al., Counc. Scient. Indus. Res., Austral., Bull. 44, 1930; Ann. Appl. Biol., *22*, 1935, 508–524; Shapovalov, Phytopath., *24*, 1934, 1149 (Abst.); Smith, Nature, *127*, 1931, 852–853; Ann. Appl. Biol., *19*, 1932, 305–330; Jour. Minist. Agr., *39*, 1933, 1097–1104; Jour. Roy. Hort. Soc., *60*, 1935, 304–310; Snyder and Thomas, Hilgardia, *10*, 1936, 257–262; Takahashi and Rawlins, Phytopath., *24*, 1934, 1111–1115; Taylor and Chamberlain, New Zealand Jour. Agr., *54*, 1937, 278–283; Whipple, Phytopath., *26*, 1936, 918–920.

Strains: A strain differing somewhat from the type, var. *typicum* H. (*loc. cit.*, 136), has been described as damaging tomatoes in the northwestern United States. It has been given a distinctive varietal name:

1a. *Lethum australiense* var. *lethale* H. (*loc. cit.*, 138). From Latin *lethalis*, deadly. Common names: Tip-blight strain of tomato spotted-wilt virus, Oregon tip-blight virus, tomato die-back streak virus, tomato tip-blight virus. Differs from the type in causing necrotic leaf spotting, stem streaking, and tip blighting in most hosts, without mottling or bronzing of foliage; yet in *Tropaeolum majus* L., there is little necrosis. In tomato, systemic necrosis, terminal shoots blighted and blackened; dead tips stand upright above living foliage. Fruits rough and pitted, with internal pockets of necrotic tissue or with subepidermal necrosis, appearing externally as concentric brown bands. (McWhorter and Milbrath, Oregon Agr. Exp. Sta., Circ. *128*, 1938; Milbrath, Phytopath., *29*, 1939, 156–168.)

SUBORDER III. **Zoophagi[illegible]e** *subordo novus.*

From Greek *phagein*, to eat, and *zoon*, an animal. Viruses infecting animals but having no plant hosts, so far as known.

Key to the families of suborder **Zoophaginae.**

1. Inducing diseases in insects as exclusive hosts.
   Family I. *Borrelinaceae*, p. 1225.
2. Inducing diseases of the pox group.
   Family II. *Borreliotaceae*, p. 1229.
3. Inducing diseases of the encephalitis group.
   Family III. *Erronaceae*, p. 1248.
4. Inducing diseases of the yellow-fever group.
   Family IV. *Charonaceae*, p. 1265.
5. Inducing diseases of the infectious anemia group.
   Family V *Trifuraceae*, p. 1282.
6. Inducing diseases of the mumps group.
   Family VI. *Rabulaceae*, p. 1284.

FAMILY I. BORRELINACEAE *FAM. NOV.*

Viruses causing polyhedral, wilt, and other diseases in arthropods. The genus *Borrelina* Paillot was originally spelled *Borrellina* by error; from Borrel, name of French scientist.

Key to the genera of family **Borrelinaceae.**

I. Known only as attacking lepidopterous insects.
   Genus I. *Borrelina*, p. 1225.
II. Known only as attacking the honey bee, a hymenopterous insect.
   Genus II. *Morator*, p. 1227.

Genus I. **Borrelina** *Paillot.*

(Compt. rend. Acad. Sci., Paris, *182*, 1926, 182.)

Viruses inducing polyhedral, wilt, and other diseases; hosts, Lepidoptera, so far as known.

The type species is *Borrelina bombycis* Paillot.

Key to the species of genus **Borrelina.**

I. Attacking silkworm.
   1. *Borrelina bombycis.*
II. Attacking nun moth.
   2. *Borrelina efficiens.*
III. Attacking gypsy moth.
   3. *Borrelina reprimens.*
IV. Attacking cabbage worm.
   4. *Borrelina brassicae.*
   5. *Borrelina pieris.*

1. **Borrelina bombycis** Paillot. (Compt. rend. Acad. Sci., Paris, *182*, 1926, 182.) From Latin *bombyx*, silkworm. (Note: Coccus-like bodies surrounded by non-staining substances, associated with the induced disease, received the provisional name *Chlamydozoon bombycis* from Prowazek, Arch. f. Protistenkunde, *10*, 1907, 363.)

Common names: Silkworm-jaundice virus, silkworm-grasserie virus, silkworm wilt virus, Gelbsucht virus, Fettsucht virus.

Host: *BOMBYCIDAE—Bombyx mori* (L.), silkworm.

Geographical distribution: Japan, Italy, France.

Induced disease: In silkworm, after prodromal period of 5 days or more, yellow spots on skin, polyhedral bodies in blood, inactivity, loss of appetite, irritability, weakening of body facilitating rupture from mechanical stress, eventual death.

Transmission: By feeding. Experimentally, also by injection.

Serological relationships: Specific agglutination, precipitation, and complement fixation.

Thermal inactivation: At 60° C in 15 to 20 minutes in blood.

Filterability: Passes Berkefeld N and V, Chamberland L_1, L_2, and L_3 filters.

Other properties: May survive at least 2 years in dry state. Stable between pH 5 and about pH 9. Sedimentation constant 17 S.

Literature: Aoki and Chigasaki, Cent. f. Bakt., I Abt., Orig., *86*, 1921, 481–485; Glaser and Lacaillade, Am. Jour. Hyg., *20*, 1934, 454–464; Glaser and Stanley, Jour. Exp. Med., *77*, 1943, 451–466; v. Prowazek, Cent. f. Bakt., I Abt., Orig., *67*, 1912, 268–284; Suzuki, Bull. Imperial Kyoto Sericultural College, *1*, 1929, 45–75; Trager, Jour. Exp. Med., *61*, 1935, 501–513.

2. **Borrelina efficiens** *spec. nov.* From Latin *efficiens*, effective, in reference to effectiveness of this virus in controlling nun-moth infestations.

Common names: Nun-moth disease virus, nun-moth wilt virus, Wipfelkrankheit virus.

Host: *LYMANTRIIDAE—Lymantria monacha* (L.), nun moth.

Geographical distribution: Europe.

Induced disease: In eggs, larvae, pupae and occasionally adults of nun moth, polyhedral bodies in affected tissues. Blood of sick larvae turbid; later, blood cells few; contents of body finally become a gray-brown, semifluid mass.

Transmission: By feeding.

Thermal inactivation: At 55 to 60° C in 5 to 10 minutes.

Filterability: Fails to pass Berkefeld and Chamberland filters.

Other properties: May remain viable at least 2 years in dry state.

Literature: Escherich and Miyajima, Naturwissens. Ztschr. f. Forst- u. Landwirtschaft, *9*, 1911, 381–402; Wachtl and Kornauth, Mitth. a. d. forstl. Versuchswesen Österreichs, *16*, 1893, 1–38; Wahl, Centralbl. Gesam. Forstw., *35*, 1909, 164–172; 212–215; *36*, 1910, 377–397; *37*, 1911, 247–268; *38*, 1912, 355–378.

3. **Borrelina reprimens** *spec. nov.* From Latin *reprimere*, to restrain.

Common name: Gypsy-moth wilt virus.

Host: *LYMANTRIIDAE—Porthetria dispar* (L.), gypsy moth.

Geographical distribution: United States.

Induced disease: In gypsy moth caterpillar, flaccidity, disintegration of tissues, eventual collapse as a watery sack. Death occurs in 13 to 29 (average 21) days after infection; caterpillar may remain attached to its support by prolegs; skin ruptures easily. Polyhedral bodies originate in nuclei of the tracheal matrix, hypodermal, fat, and blood cells.

Transmission: By feeding on contam-

inated foliage. Not through undamaged skin.

Filterability: Passes Berkefeld N, not Pasteur-Chamberland F, filter.

Literature: Chapman and Glaser, Jour. Econ. Entomol., *8*, 1915, 140–150; *9*, 1916, 149–167; Glaser, Jour. Agr. Res., *4*, 1915, 101–128; Science, *48*, 1918, 301–302; Glaser and Chapman, Jour. Econ. Entomol., *6*, 1913, 479–488.

4. **Borrelina brassicae** Paillot. (Compt. rend. Acad. Sci., Paris, *182*, 1926, 182.) From name of host, *Pieris brassicae.*

Common name: Cabbage-worm grasserie virus.

Host: *PIERIDAE—Pieris brassicae* (L.), cabbage worm.

Induced disease: In cabbage worm, no nuclear or cytoplasmic inclusions; nuclei of fat and hypodermal cells hypertrophied and soon disorganized.

Transmission: By feeding.

Other properties: Described as submicroscopic in size, intracytoplasmic.

Literature: Paillot, *loc. cit.*; Ann. Inst. Pasteur, *40*, 1926, 314–452; L'infection chez les insectes. Immunité et symbiose, 535 pages, Trévoux, Patissier, 1933.

5. **Borrelina pieris** Paillot. (Compt. rend. Acad. Sci., Paris, *182*, 1926, 182.) From New Latin *Pieris*, generic name of host.

Common name: Virus of nuclear disease of pierids.

Host: *PIERIDAE—Pieris brassicae* (L.), cabbage worm.

Induced disease: In cabbage worm, body yellowish below, tears easily just before death; chromatin of nuclei in fat and blood cells condensed in irregular masses; cytoplasmic inclusions staining faintly red in Giemsa preparations.

Transmission: By feeding.

Other properties: Described as intracytoplasmic, less than 0.1 micron in diameter.

Literature: Paillot, *loc. cit.*; Ann. Inst. Pasteur, *40*, 1926, 314–452; L'infection chez les insectes. Immunité et symbiose, 535 pages, Trévoux, Patissier, 1933.

Appendix: *Borrelina flacheriae* quoted from Paillot, L'infection chez les insects. 535 pp., Trevoux, Patissier, 1935, see p. 96. Cause of gattine in the silkworm, *Bombyx mori* L. No previous reference to a description of this species has been found.

Genus II. Morator *gen. nov.*

Only one species at present, inducing the disease known as sacbrood of the honey bee. Generic name from Latin *morator*, loiterer. The type, and only, species is *Morator aetatulae spec. nov.*

1. **Morator aetatulae** *spec. nov.* From Latin *aetatula*, early period of life, in reference to attack on immature stages of host, exclusively.

Common name: Honey-bee sacbrood virus.

Host: *APIDAE—Apis mellifera* L., honey bee (immature stages only).

Insusceptible species: *LYMANTRIIDAE—Porthetria dispar* (L.), gypsy moth.

Geographical distribution: United States.

Induced disease: In the honey bee, immature stages only are susceptible; infected larvae die, usually after capping, some of the dead brood being uncapped by the bees. Occasionally caps are punctured. Affected areas of comb are usually small and scattered. Each larva is extended along its cell, head turned upward toward the roof. A larva recently dead appears light yellow, light gray, or light brown, soon darkening to brown or almost black. Cuticle of dead larva tough, permitting extraction of the sac-

like mass without rupture; contents watery with many suspended, fine, brown particles. There are no characteristic intracellular bodies in affected tissues. Dead larvae eventually dry down to form scales that are black and roughened, that separate readily from the cell wall, and that may be lifted out intact. Colonies tend to lose virus spontaneously.

Transmission: By contamination of food. Not by hands, clothing, or tools. Perhaps through water supply of insects.

Thermal inactivation: In water, at 58° C in 10 minutes. In honey, at 70 to 73° C in 10 minutes.

Filterability: Passes Berkefeld and Pasteur-Chamberland filters.

Other properties: Withstands drying 20, not 22, days, exposure to sunlight 7 hours or less, storage in honey a month or more, ½ to 2 per cent aqueous solutions of carbolic acid 3 weeks or more.

Literature: McCray and White, U. S. Dept. Agr., Dept. Bull. 671, 1918; White, U. S. Dept. Agr., Bur. of Entomol., Circ. 169, 1913; U. S. Dept. Agr., Dept. Bull. 92, 1914; *ibid.*, Dept. Bull. 431, 1917.

FAMILY II. BORRELIOTACEAE *FAM. NOV.*

Viruses of the Pox Group, inducing diseases characterized in general by discrete primary and secondary lesions of the nature of macules, papules, vesicles, or pustules.

Key to the genera of family **Borreliotaceae.**

I. Viruses of the Typical Pox-Disease Group.
Genus I. *Borreliota*, p. 1229.
II. Viruses of the Varicella Group.
Genus II. *Briareus*, p. 1233.
III. Viruses of the Herpes Group.
Genus III. *Scelus*, p. 1234.
IV. Viruses of the Foot-and-Mouth-Disease Group.
Genus IV. *Hostis*, p. 1239.
V. Viruses of the Wart-Disease Group.
Genus V. *Molitor*, p. 1240.

Genus I. **Borreliota** *Goodpasture.*

(Science, 77, 1933, 121.)

Viruses of the Typical Pox-Disease Group, inducing diseases characterized by formation of papules, pustules, and scabs, shed with or without scarring. Generic name from *Borrel*, investigator who first discovered the specific granules of fowl pox and Latinized name of the smallest Greek letter, *iota*, signifying smallest particle. The name *Cytoryctes variolae* Guarnieri 1892 was based on intracellular inclusions, Guarnieri bodies, as supposed sporozoan parasites (Calkins, Jour. Med. Res., *11*, 1904, 136–172).

The type species is *Borreliota avium* Goodpasture.

Key to the species of genus **Borreliota.**

I. Affecting domestic fowl.
1. *Borreliota avium.*
II. Affecting man principally, although strains have become adapted to cow, rabbit, etc.
2. *Borreliota variolae.*
III. Affecting swine.
3. *Borreliota suis.*

1. **Borreliota avium** (Lipschütz) Goodpasture. (*Strongyloplasma avium* Lipschütz, in Kolle, Kraus and Uhlenhuth, Handbuch der pathogenen Mikroorganismen, 3 Auft., *8*, 1930, 314; Goodpasture, Science, *77*, 1933, 121.) From Latin *aves*, fowl of the air.

Common names: Fowl-pox virus; also known as poultry-pox virus, chicken-pox virus (but not the virus of the same name attacking man rather than the chicken), or virus of epithelioma contagiosum of fowls; strains have been studied under the names Kikuth's canary virus and pigeon-pox virus.

Hosts: Chicken, turkey, pigeon, goose, duck, guinea fowl, quail, hawk, pheasant, partridge, bunting sparrow, canary. Experimentally, also English sparrow, chick embryo.

Insusceptible species: Man, goat, sheep, mouse, rat, guinea pig.

Geographical distribution: Europe, Asia, North America; perhaps coextensive with the area in which chickens are grown under conditions of domestication.

Induced disease: In chicken, hyperplastic nodular lesions of the skin, diphtheritic membranes in mouth and throat, discharges from eyes and nose; nodules eventually dry up and fall off, usually without leaving scars. Inclusion bodies, known as Bollinger bodies, believed to represent aggregates of minute Borrel bodies or virus particles, leave much grayish-white ash when incinerated; break readily after digestion by 1 per cent trypsin in 0.2 per cent sodium bicarbonate. Borrel bodies coccoid, 0.25 microns in diameter. On chorioallantoic membrane of chick embryo, proliferation and hyperplasia, or necrosis.

Transmission: By contact, perhaps through wound infection. By bloodsucking dipterous insects. Experimentally, by scarification of skin or buccal mucosa; by intravenous, intradermal, subcutaneous, intramuscular, or intraperitoneal inoculation. May be passed in series by nasal instillation in chickens, obvious mucosal changes occurring only occasionally. Experimentally, by mosquitoes (*CULICIDAE*), *Aëdes aegypti* L., *A. stimulans* Walker, *A. vexans* Meigen (as long as 27 days from time of feeding on infective material), and *Culex pipiens* L. (indefinitely after infective feeding, as long as the individual mosquito lives); in *C. pipiens*, the virus has been found also under natural conditions.

Serological relationships: Neutralizing and elementary-body-agglutinating antisera specific. Antivaccinial serum from rabbit ineffective against fowl-pox virus, although neutralizing vaccinia virus.

Immunological relationships: No cross immunity with respect to vaccinia virus in the chicken.

Thermal inactivation: At 60° C in 8 minutes; at 56° C in 30 minutes.

Filterability: Passes Berkefeld V, not Chamberland L_2, filter candle.

Other properties: Drying at room temperature *in vacuo* does not inactivate. Viable after storage at least 24 months at 0 to 4° C, dry.

Strains: A strain known as Kikuth's canary virus has been studied in some detail. When introduced into the rabbit it induces formation of neutralizing antibodies that react strongly with homologous virus, moderately against fowl-pox virus. Antivaccinial serum is ineffective against it. In canaries, it induces proliferation of dermal epithelium with cytoplasmic inclusions, the inflammatory process being characterized by predominantly mononuclear cells with vacuolated cytoplasm; in the lung there is massive accumulation of large mononuclear cells containing the specific cytoplasmic inclusions; the disease is regularly fatal. Passes Berkefeld N filter. Size estimated as 120 millimicrons by centrifugation. (Bechhold and Schlesinger, Ztschr. f. Hyg., *115*, 1933, 354–357; Burnet, Jour. Path. and Bact., *37*, 1933, 107–122; Burnet and Lush, Brit. Jour. Exp. Path., *17*, 1936, 302–307; Gaede, Cent. f. Bakt., I Abt., Orig., *135*, 1935, 342–346; Kikuth and Gollub, *ibid.*, *125*, 1932, 313–320.)

Literature: Andervont, Am. Jour. Hyg., *6*, 1926, 719–754; Brandly and Dunlap, Jour. Am. Vet. Med. Assoc., *95*, 1939, 340–349; Brandly et al., Am. Jour. Vet. Res., *2*, 1941, 190–192; Brody, Cornell Agr. Exp. Sta. (Ithaca). Memoir 195, 1936; Buddingh, Jour. Exp. Med., *67*, 1938, 933-940; Burnet and Lush, Brit. Jour. Exp. Path., *17*, 1936, 302–307; Danks, Am. Jour. Path., *8*, 1932, 711–716; Findlay, Proc. Roy. Soc. London, Ser. B, *102*, 1928, 354–379; Goodpasture and A. M. Woodruff, Am. Jour. Path., *6*, 1930, 699–712; Goodpasture and C. E. Woodruff, *ibid.*, *7*, 1931, 1–8; Irons, Am. Jour. Hyg., *20*, 1934, 329–351; Kligler and Ashner, Proc. Soc. Exp. Biol. and Med., *28*, 1931, 463–465; Kligler et al., Jour. Exp. Med., *49*, 1929, 649–660; Ledingham, Lancet, *221*, 1931 (*2*), 525–526; Ludford and Findlay, Brit. Jour. Exp. Path., 7 1926, 256–264; Matheson et al, Poultry Science, *10*, 1931, 211–223; Megrail, Am. Jour. Hyg., *9*, 1929, 462–465; Nelson, Jour. Exp. Med., *74*, 1941, 203–212; A. M. Woodruff, and Goodpasture, Am. Jour.

Path., 7, 1931, 209–222; C. E. Woodruff, *ibid.*, 6, 1930, 169–174; C. E. Woodruff, and Goodpasture, *ibid.*, 5, 1929, 1–10; 6, 1930, 713–720.

2. **Borreliota variolae** (Lipschütz) Goodpasture. (*Strongyloplasma variolae* Lipschütz, in Kolle, Kraus and Uhlenhuth, Handbuch der pathogenen Mikroorganismen, 3 Aufl., 8, 1930, 317; Goodpasture, Science, 77, 1933, 121.) From New Latin *variola*, smallpox.

Common names: Variola virus, smallpox virus. Most studies of this virus have been concerned with the vaccinia strain; see Strains below.

Hosts: Man, cow and rabbit are susceptible to strains that appear especially adapted to them (see *Strains* below). Experimentally, also chicken (and chick embryo); *Chrysemys marginata*, turtle; guinea pig, horse, pig; *Macaca mulatta* (Zimmermann), rhesus monkey; *M. irus*, cynomolgus monkey; orang-outang; *Macacus fuscatus*.

Geographical distribution: Nearly world-wide, except where excluded by isolation or protective vaccination.

Induced disease: In man, mild to severe smallpox, sometimes with pocks few and discrete but often with pocks numerous and coalescing; onset sudden, 6 to 22 days (average 12) after infection; headache, vomiting, fever, often rashes on body before appearance of the specific eruption, bright red spots becoming vesicular and eventually pustular; the pocks are commonest on face, forearms, wrists, palms of hands, and soles of feet; pustules gradually become flattened scabs and drop off, leaving no scar if superficial and not secondarily infected; in hemorrhagic smallpox there are numerous hemorrhages into the skin and mortality is high, death often preceding formation of pustules; severity of disease and mortality roughly proportional to the amount of eruption on the face.

Transmission: By contact with infected individuals or contaminated articles; perhaps by droplet infection, obvious primary lesions characterizing experimental transmission by scarification but not natural spread.

Serological relationships: Hyperimmune calf serum neutralizes virus. Neutralization depends on an antibody not involved in agglutination and precipitation. Antivaccinial serum gives complement fixation in the presence of variola virus. One agglutinogen (L) labile at 56° C, one (S) stable at 95° C; both are parts of a single protein but can be degraded independently; chymotrypsin destroys activity of S, not L. Increasing neutralization in immune serum and virus mixtures *in vitro* with progressive incubation; partial reactivation on simple dilution. Antivaccinial sera agglutinate Paschen bodies of vaccinia but not Borrel bodies of fowl pox; anti-fowl-pox sera agglutinate Borrel but not Paschen bodies. No cross reactions with herpes virus.

Immunological relationships: In vaccinia-immune swine, protective substances pass *via* colostrum, conveying passive immunity to young for 2 to 3 months after birth. In man, immunity against variola virus is conferred by earlier infection with vaccinia strain. In hen, previous infection with fowl-pox virus does not immunize with respect to vaccinia virus.

Thermal inactivation: At 55° C in 20 minutes.

Filterability: Passes Berkefeld V, not Mandler, filter.

Other properties: Density about 1.16. Sedimentation constant 5000×10^{-13} (corrected to water at 20° C). Retains activity in glycerine best at pH 7.0. 0.1 per cent gelatin delays spontaneous inactivation at 5 to 10° C. Withstands absolute alcohol, ether, acetone, and petroleum ether 1 hour in dry samples at 4° C without decrease in activity. Inactivated without disruption by sonic vibrations of about 8900 cycles per second. Diameter estimated as 125 to 175 millimicrons by filtration; 236 to 252 millimicrons by ultracentrifugation. Electron micrographs show limiting surface

membrane, dense granules (usually 5) within; tendency to rectangular outlines with rounded corners. At least 5.6 per cent of virus is reported to be thymonucleic acid. Contains nitrogen, 15.3 per cent; carbon, 33.7 per cent; phosphorus, 0.57 per cent; phospholipid (lecithin), 2.2 per cent; neutral fat, 2.2 per cent; reducing sugars after hydrolysis, 2.8 per cent; cystine, 1.9 per cent; copper, 0.05 per cent.

Strains: Besides the typical variola strain, var. *hominis* Goodpasture (Science, 77, 1933, 121), several distinctive strains have been studied. A spontaneous cowpox strain differs in some antigens but affords cross immunity with respect to var. *bovis* Goodpasture (*loc. cit.*, 121), vaccinia virus, which in turn immunizes against typical variola virus. A spontaneous rabbit-pox strain, serologically resembling neurovaccine virus, is believed to exist independently in Europe and the United States. The varieties *equi* (horse-pox virus), *porci* (swine strain), and *ovium* (sheep and goat pox virus) have been attributed to this species by Goodpasture (*loc. cit.*, 121). The alastrim strain (causing *variola minor*) differs from the type in producing a relatively mild disease in man and in inducing the formation of a distinctive type of intracellular inclusion in affected tissues.

Literature: Amies, Jour. Path. and Bact., *47*, 1938, 205–222; Andervont, Am. Jour. Hyg., *7*, 1927, 804–810; Behrens and Ferguson, Jour. Inf. Dis., *56*, 1935, 84–88; Behrens and Nielson, *ibid.*, *56*, 1935, 41–48; Buddingh, Am. Jour. Hyg., *38*, 1943, 310–322; Craigie and Wishart, Brit. Jour. Exp. Path., *15*, 1934, 390–398; Jour. Exp. Med., *64*, 1936, 819–830; Dearing, Am. Jour. Hyg., *20*, 1934, 432–443; Douglas et al., Jour. Path. and Bact., *32*, 1929, 99–120; Downie, Brit. Jour. Exp. Path., *20*, 1939, 158–176; Eagles, *ibid.*, *16*, 1935, 181–188; Elford and Andrewes, Brit. Jour. Exp. Path., *13*, 1932, 36–42; Goodpasture, Woodruff, and Buddingh, Am. Jour. Path., *8*, 1932, 271–282; Green et al., Jour. Exp. Med., *75*, 1942, 651–656; Greene, *ibid.*, *61*, 1935, 807–831; Herzberg, Ztschr. Immunitätsforsch. u. exper. Therap., *86*, 1935, 417–441; Hoagland et al., Jour. Exp. Med., *71*, 1940, 737–750; *72*, 1940, 139–147; *74*, 1941, 69–80, 133–144; *76*, 1942, 163–173; Hu et al., Jour. Exp. Med., *63*, 1936, 353–378; Keogh, Jour. Path. and Bact., *43*, 1936, 441–454; Ledingham, Brit. Jour. Exp. Path., *5*, 1924, 332–349; Jour. Path. and Bact., *35*, 1932, 140–142; Macfarlane and Dolby, Brit. Jour. Exp. Path., *21*, 1940, 219–227; Macfarlane and Salaman, *ibid.*, *19*, 1938, 184–191; McFarlane et al., *ibid.*, *20*, 1939, 485–501; Moriyama, Arch. f. Virusforsch., *1*, 1940, 422–429; Nelson, Jour. Exp. Med., *60*, 1934, 287–291; *78*, 1943, 231–239; Nye and Parker, Am. Jour. Path., *5*, 1929, 147–155; Parker, Jour. Exp. Med., *67*, 1938, 361–367, 725–738; Parker and Muckenfuss, Jour. Infect. Dis., *53*, 1933, 44–54; Parker and Rivers, Jour. Exp. Med., *62*, 1935, 65–72; *64*, 1936, 439–452; *65*, 1937, 243–249; Paschen, Deutsch. med. Wchschr., *39*, 1913, 2132–2136; Pearce et al., Jour. Exp. Med., *63*, 1936, 241–258, 491–507; Jour. Path. and Bact., *43*, 1936, 299–312; Pickels and Smadel, Jour. Exp. Med., *68*, 1938, 583–606; Rhodes and van Rooyen, Jour. Path. and Bact., *44*, 1937, 357–363; Rivers and Ward, Jour. Exp. Med., *58*, 1933, 635–648; *62*, 1935, 549–560; Rivers et al., *ibid.*, *65*, 1937, 677–685; *69*, 1939, 857–866; Rosahn et al., Jour. Exp. Med., *63*, 1936, 259–276, 379–396; Rosenau and Andervont, Am. Jour. Hyg., *13*, 1931, 728–740; Salaman, Brit. Jour. Exp. Path., *18*, 1937, 245–258; Shedlovsky and Smadel, Jour. Exp. Med., *75*, 1942, 165–178; Smadel and Rivers, *ibid.*, *75*, 1942, 151–164; Smadel et al., *ibid.*, *68*, 1938, 607–627; *71*, 1940, 373–389; *77*, 1943, 165–171; Smith, Jour. Path. and Bact., *33*, 1930, 273–282; Sprunt, Proc. Soc. Exp. Biol. and Med., *51*, 1942, 226–227; Jour. Exp. Med., *75*, 1942, 297–304; Stritar and Hudson, Am. Jour. Path., *12*, 1936, 165–174; Ward, Jour. Exp. Med., *50*, 1929, 31–40.

3. Borreliota suis *spec. nov.* From Latin *sus*, swine.

Common name: Swine-pox virus (not

the vaccinia strain of variola virus in swine).

Host: *SUIDAE—Sus scrofa* L., domestic swine.

Insusceptible species: Rabbit.

Geographical distribution: United States (Iowa).

Induced disease: In swine, locally, reddened hyperemic papules 3 to 7 mm in diameter; papules become briefly vesicular, then change gradually to true pustules, finally forming dark brown to blackish scabs which are shed after a few weeks without scarring; no secondary lesions in hogs free from lice, but in infested animals numerous secondary lesions appear 1 to 2 weeks after primary lesions and are commonly most numerous in the inguinal and axillary regions. Mortality negligible but growth retarded. Virus has been recovered from hog louse after feeding on affected swine.

Transmission: By hog louse, *Haematopinus suis* (*HAEMATOPINIDAE*), probably mechanically. By experimental scarification of skin.

Serological relationships: No reaction with neutralizing sera specific for vaccinia virus.

Immunological relationships: Specific immunity in swine after attack, but no cross immunity with respect to vaccinia virus.

Filterability: Passes Berkefeld V and N filters.

Literature: Csontos and von Nyiredy, Deutsch. tierärztl. Wchnschr., *41*, 1933, 529–532; Schwarte and Biester, Am. Jour. Vet. Res., *2*, 1941, 136–140; Shope, Arch. f. Virusforsch., *1*, 1940, 457–467.

Genus II. **Briareus** *gen. nov.*

Viruses of the Varicella Group, causing diseases characterized by reddened spots and rings in affected tissues, becoming papular or vesicular. Generic name from Latin *Briareus*, name of a hundred-armed giant.

The type species is *Briareus varicellae spec. nov.*

Key to the species of genus **Briareus.**

I. Causing chicken pox and herpes zoster in man.
   1. *Briareus varicellae.*

II. Causing measles in man.
   2. *Briareus morbillorum.*

1. Briareus varicellae *spec. nov.* From New Latin *varicella*, chicken pox.

Common names: Varicella virus, chicken-pox virus; much evidence for identity with so-called herpes-zoster virus has been presented.

Host: *HOMINIDAE—Homo sapiens* L., man.

Insusceptible species: Chick embryo.

Geographical distribution: World-wide.

Induced disease: In man, usually abrupt onset, rash at first macular, soon papular and vesicular; vesicles generally discrete, soon rupturing, healing with scab formation and itching; separation of deeper scabs may leave persistent scars; in severe cases there may be stomatitis, laryngitis, and nasal lesions. In human skin grafted on chorioallantois of chick embryo, experimentally, pustular lesions as in natural disease, with intranuclear acidophilic inclusions; no gross vesiculation.

Transmission: By contact. By spread of droplets. Children in contact with herpes zoster patients sometimes contract varicella.

Serological relationships: Majority of herpes zoster sera that agglutinate zoster antigen also agglutinate elementary bodies of varicella; complement fixation tests also indicate relationship of virus from herpes zoster and varicella. Chicken-pox sera do not flocculate smallpox brain-virus antigen.

Immunological relationships: Children previously having varicella are immune to inoculation with herpes zoster virus.

Literature: Amies, Brit. Jour. Exp. Path., *15*, 1934, 314–320; Brain, *ibid.*, *14*, 1933, 67–73; Bruusgaard, Brit. Jour. Derm. Syph., *44*, 1932, 1–24; Goodpasture and Anderson, Am. Jour. Path., *20*, 1944, 447–453; Havens and Mayfield, Jour. Inf. Dis., *50*, 1932, 242–248; Irons et al., Am. Jour. Hyg., *33*, (B), 1941, 50–55; Kundratitz, Monatsschr. Kinderheilk., *29*, 1925, 516–523; Lipschütz and Kundratitz, Wien. klin. Woch., *38*, 1925, 499–503.

2. **Briareus morbillorum** *spec. nov.* From New Latin *morbilli*, measles.

Common name: Measles virus.

Host: *HOMINIDAE—Homo sapiens* L., man. Experimentally, also *CERCOPITHECIDAE—Macaca mulatta* (Zimmermann), rhesus monkey. *PHASIANIDAE—Gallus gallus* (L.), chick embryo (no lesions, but 30 serial passages).

Geographical distribution: World-wide except in isolated communities.

Induced disease: In man, after incubation period of 7 to 21 days, bright red spots on buccal mucosa, especially near first molar tooth (Koplik's spots) followed by rash on face, head, neck, then arms, trunk, and legs; papules often crescents, lesions usually discrete; rash fades, leaving brownish discoloration and desquamation.

Transmission: By contact. By droplets.

Serological relationships: Convalescent serum is reported to modify the course of the induced disease if administered intravenously in the preeruptive stage.

Immunological relationships: Specific immunity in man after attack.

Thermal inactivation: At 55° C in 15 minutes.

Filterability: Passes Berkefeld N filter candle and Seitz EK disks.

Other properties: Viable at −35° C for at least 4 weeks. Not inactivated by 10 per cent anesthetic ether in 40 minutes.

Literature: Blake and Trask, Jour. Exp. Med., *33*, 1921, 385–412; Gordon and Knighton, Am. Jour. Path., *17*, 1941, 165–176; Hedrich, Am. Jour. Hyg., *17*, 1933, 613–636; Kohn et al., Jour. Am. Med. Assoc., *111*, 1938, 2361–2364; Rake and Shaffer, Jour. Immunol., *38*, 1940, 177–200; Rake et al., Jour Inf. Dis., *69*, 1941, 65–69; Scott and Simon, Am. Jour. Hyg., *5*, 1925, 109–126.

Genus III. Scelus *gen. nov.*

Viruses of the Herpes Group, inducing diseases characterized in general by vesicular primary lesions, sometimes with subsequent involvement of the nervous system. Generic name from Latin *scelus*, rascal.

The type species is *Scelus recurrens spec. nov.*

Key to the species of genus Scelus.

I. In man, cause of so-called fever blisters, herpes febrilis.
  1. *Scelus recurrens.*

II. In swine, cause of pseudorabies.
  2. *Scelus suillum.*

III. In monkey.
  3. *Scelus beta.*

IV. In rabbit, course of the induced disease in nature unknown.
  4. *Scelus tertium.*

V. In sheep, cause of ovine balano-posthitis.
  5. *Scelus ulceris.*

VI. In mice, cause of ectromelia.
  6. *Scelus marmorans.*

VII. In cattle, cause of erosive stomatitis.
  7. *Scelus bovinum.*

1. Scelus recurrens *spec. nov.* From Latin *recurrere*, to recur. Note: The name *Neurocystis herpetii* Levaditi and Schoen (Compt. rend. Soc. Biol., Paris, *96*, 1927, 961) was applied provisionally to the causative microorganism of herpes, in the expectation that future research would show inclusion bodies in affected tissues to be stages in its life cycle.

Common names: Herpes virus, virus of herpes simplex, virus of herpes febrilis (not herpes zoster virus, for which see varicella virus), virus of keratitis dendritica, virus of aphthous stomatitis (of man).

Host: *HOMINIDAE—Homo sapiens* L., man. Experimentally, also rabbit, guinea pig, white mouse, cat, goose, hedgehog, and, though difficult to infect, dog and pigeon. Chick embryo (but not chicken). Also *CERCOPITHECIDAE—Cercocebus fuliginosus* E. Geoffrey, *Macacus cynomolgus*. *CEBIDAE—Cebus olivaceus*.

Insusceptible species: White rat; *Bufo viridis*; *Cercopithecus callithrix*; chicken (except embryo).

Geographical distribution: Probably world-wide.

Induced disease: In man, usually acquired in first three years of life, sometimes as aphthous stomatitis; virus probably retained often through life, sometimes with periodic reappearance of dermal lesions, which are vesicular and heal soon. In white mouse, by experimental inoculation of skin, small inflamed vesicular primary lesions about 5 days after inoculation, usually forming scabs and healing a few days later, but sometimes persisting; if on tail, followed by swelling and paralysis of tail, ascending paralysis and death, or by recovery with acquired immunity; if near head, followed by encephalitis and death; intraperitoneal and sometimes other inoculations immunize; relapse with recurrence of primary lesions rare. In chick embryo, white, opaque, circular or ring-like primary lesions of small size on chorioallantoic membrane, with or without necrotic secondary lesions in liver, heart, lungs, spleen, and kidneys; virus enters membrane 1 to 4 hours after it is dropped on its surface; primary lesions may be counted in 48 hours.

Transmission: By contacts. Experimentally, by skin scarification; in guinea pig, by feeding.

Serological relationships: Distant relationship to pseudorabies virus, *Scelus suillum*, shown by moderate protection against this virus conferred by some anti-herpes sera. No relationship to vaccinia virus or to virus III of rabbits demonstrable by neutralization tests. Specific complement fixation. Neutralizing antibody forms reversible union with virus, at least for a time, though with strong mixtures partial irreversibility finally occurs.

Immunological relationships: Formalinized virus and non-lethal strains of virus immunize specifically. No cross immunity with vaccinia virus.

Thermal inactivation: At 50 to 52° C in 30 minutes, when moist; at 90 to 100° C in 30 minutes, when dry. At 41.5° C in 50 to 80 hours.

Filterability: Passes Berkefeld V filter with slight loss.

Other properties: Diameter, by centrifugation, computed as 180 to 220 millimicrons; by filtration, 100 to 150 millimicrons. Specific gravity, 1.15. Inactivated by repeated freezing and thawing; also by pressure of 3000 atmospheres for 30 minutes. Viable dry at least 18 months at 4° C, in 50 per cent glycerine at least 6 months. Not inactivated at 4° C in 1 per cent aqueous gentian violet. Charged negatively in solutions of hydrogen-ion concentration up to about pH 8. Isoelectric point, pH 7.2 to 7.6. Inactivated by incubation *in vitro* at pH 6 with synthetic vitamin C (ascorbic acid).

Literature: Anderson, Science, *90*, 1939, 497; Am. Jour. Path., *16*, 1940, 137–156; Andervont, Jour. Inf. Dis., *44*, 1929, 383–393; *45*, 1929, 366–385; *49*, 1931, 507–529; Andrewes, Jour. Path. and Bact., *33*, 1930, 301–312; Bassett et al., Compt. rend. Acad. Sci., Paris, *200*, 1935, 1882–1884; Bechhold and Schlesinger, Ztschr.

f. Hyg., *115*, 1933, 342–353; Bedson, Brit. Jour. Exp. Path., *12*, 1931, 254–260; Bedson and Bland, *ibid.*, *9*, 1928, 174–178; Blanc and Caminopetros, Compt. rend. Soc. Biol., Paris, *84*, 1921, 859–860; Boak et al., Jour. Exp. Med., *71*, 1940, 169–173; Brain, Brit. Jour. Exp. Path., *13*, 1932, 166–171; Buggs and Green, Jour. Inf. Dis., *58*, 1936, 98–104; Burnet and Lush, Jour. Path. and Bact., *48*, 1939, 275–286; *49*, 1939, 241–259; Lancet, *236*, 1939 (*1*), 629–631; Burnet et al., Austral. Jour. Exp. Biol. and Med. Sci., *17*, 1939, 35–40; Dawson, Am. Jour. Path., *9*, 1933, 1–6; Elford et al., Jour. Path. and Bact., *36*, 1933, 49–54; Findlay and MacCallum, Lancet, *238*, 1940 (*1*), 259–261; Fischl and Schaefer, Klin. Wochnschr., *8*, 1929, 2139–2143; Flexner, Jour. Gen. Physiol., *8*, 1927, 713–726; Jour. Exp. Med., *47*, 1928, 9–36; Friedenwald, Arch. Ophthalmol., *52*, 1923, 105–131; Goodpasture, Medicine, *8*, 1929, 223–243; Goodpasture and Teague, Jour. Med. Res., *44*, 1923, 121–138; Gunderson, Arch. Opthalmol., *15*, 1936, 225–249; Holden, Jour. Inf. Dis., *50*, 1932, 218–236; Keddie and Epstein, Jour. Am. Med. Assoc., *117*, 1941, 1327–1330; Levaditi and Lepine, Compt. rend. Acad. Sci., Paris, *189*, 1929, 66–68; Levaditi and Nicolau, Compt. rend. Soc. Biol., Paris, *90*, 1924, 1372–1375; Long, Jour. Clin. Investigation, *12*, 1933, 1119–1125; Magrassi, Boll. Ist. Sieroterap. Milanese, *14*, 1935, 773–790; McKinley, Proc. Soc. Exp. Biol. and Med., *26*, 1928, 21–22; Naegeli and Zurukzoglu, Cent. f. Bakt. I Abt., Orig., *135*, 1935, 297–299; Nicolau and Kopciowska, Ann. Inst. Pasteur, *60*, 1938, 401–431; Parker and Nye, Am. Jour. Path., *1*, 1925, 337–340; Perdrau, Proc. Roy. Soc. London, Ser. B, *109*, 1931, 304–308; Jour. Path. and Bact., *47*, 1938, 447–455; Remlinger and Bailly, Comp. rend. Soc. Biol., Paris, *94*, 1926, 734–736; 1064–1066; *95*, 1926, 1542–1545; *96*, 1927, 404–406; 1126–1128; *97*, 1927, 109–111; Sabin, Brit. Jour. Exp. Path., *15*, 1934, 372–380; Schultz and Hoyt, Jour. Immunol., *15*, 1928, 411–419; Shaffer and Enders, *ibid.*, *37*, 1939, 383–411; Simon, International Clinics, Series 37, *3*, 1927, 123–128; Smith et al., Am. Jour. Path., *17*, 1941, 55–68; Warren et al., Jour. Exp. Med., *71*, 1940, 155–168; Weyer, Proc. Soc. Exp. Biol. and Med., *30*, 1932, 309–313; Zinsser, Jour. Exp. Med., *49*, 1929, 661–670; Zinsser and Seastone, Jour. Immunol., *18*, 1930, 1–9; Zurukzoglu and Hruszek, Cent. f. Bakt. I Abt., Orig., *128*, 1933, 1–12.

2. **Scelus suillum** *spec. nov.* From Latin *suillus*, pertaining to swine.

Common names: Pseudorabies virus, mad-itch virus.

Hosts: Domestic cattle, swine, dog, cat, horse, sheep. Experimentally, also rabbit, guinea pig, white rat, white mouse, gray field mouse, duck, chicken, chick embryo; *Macaca mulatta* (Zimmermann), rhesus monkey.

Geographical distribution: France, Germany, Hungary, Holland, Denmark, Switzerland, Siberia, Brazil, United States.

Induced disease: In cattle, licking of affected area, usually somewhere on hindquarters, sudden decrease in milk production in dairy animals, violent rubbing, biting, and gnawing of lesion; swelling and discoloration of affected parts with oozing of serosanguineous fluid; grinding of teeth and excessive salivation in some individuals; death, preceded by clonic convulsions, violent tossing of head, and shallow respiration, usually 36 to 48 hours after onset. In pig, mild but highly contagious disease; slight nerve-cell degeneration, predominance of vascular and interstitial lesions.

Transmission: By contact in swine, not in cattle. By feeding in cats, brown rats, and swine.

Serological relationships: Cross neutralization between constituent strains. Anti-herpes sera protect in some cases against small, but constantly infective, doses of pseudorabies virus.

Literature: Aujeszky, Cent. f. Bakt. I Abt., Orig., *32*, 1902, 353–357; F. B. Bang, Jour. Exp. Med., *76*, 1942, 263–270;

O. Bang, Acta path. et microbiol. Scand., Suppl., *11*, 1932, 180–182; Carini and Maciel, Bull. Soc. Path. exot., *5*, 1912, 576–578; Følger, Acta path. et microbiol. Scand., Suppl., *11*, 1932, 182–187; Glover, Brit. Jour. Exp. Path., *20*, 1939, 150–158; Gowen and Schott, Am. Jour. Hyg., *18*, 1933, 674–687; Hurst, Jour. Exp. Med., *58*, 1933, 415–433; *59*, 1934, 729–749; *63*, 1936, 449–463; Köves and Hirt, Arch. wissensch. u. prakt. Tierheilk., *68*, 1934, 1–23; Morrill and Graham, Am. Jour. Vet. Res., *2*, 1941, 35–40; Brit. Jour. Exp. Path., *15*, 1934, 372–380; Shope, Proc. Soc. Exp. Biol. and Med., *30*, 1932, 308–309; Jour. Exp. Med., *54*, 1931, 233–248; *57*, 1933, 925–931; *62*, 1935, 85–99, 101–117, Traub, *ibid.*, *58*, 1933, 663–681; *61*, 1935, 833–838.

3. **Scelus beta** *spec. nov.* From *beta*, second letter of Greek alphabet, in reference to common name.

Common name: B virus.

Hosts: *HOMINIDAE—Homo sapiens* L., man. *CERCOPITHECIDAE—Macaca mulatta* (Zimmermann), rhesus monkey. Experimentally, also *LEPORIDAE—Oryctolagus cuniculus* (L.), rabbit. *CAVIIDAE—Cavia porcellus* (L.), guinea pig.

Geographical distribution: United States (from captive monkeys and man).

Induced disease: In man, local and relatively insignificant lesion on bitten part, later flaccid paralysis of legs, urinary retention, ascending paralysis, and death by respiratory failure. In *Macaca mulatta*, experimentally by intracutaneous injection, hemorrhagic or vesiculo-pustular lesions without later involvement of central nervous system but with subsequent acquired immunity. Acidophilic intranuclear inclusions in lesions.

Transmission: To man, by bite of monkey. To monkey, experimentally, by injection.

Literature: Burnet et al., Austral. Jour. Exp. Biol. and Med. Sci., *17*, 1939, 35–40, 41–51; Sabin, Brit. Jour. Exp. Path., *15*, 1934, 248–268, 268–279, 321–334; Sabin and Hurst, *ibid.*, *16*, 1935, 133–148; Sabin and Wright, Jour. Exp. Med., *59*, 1934, 115–136.

4. **Scelus tertium** *spec. nov.* From Latin *tertius*, third.

Common name: Virus III of rabbits.

Host: *LEPORIDAE—Oryctolagus cuniculus* (L.), domestic rabbit.

Insusceptible species: No obvious disease in inoculated guinea pig, white mouse, monkey (*Macaca mulatta* Zimmermann), rat, or man; hence the assumption that these are naturally immune, but they may be merely tolerant or klendusic.

Geographical distribution: United States (apparently spontaneous in some individuals of the laboratory rabbit).

Induced disease: In domestic rabbit, experimentally, after incubation period of 4 to 6 days, failure to eat, loss of weight, occasionally diarrhea and temperatures of 104 to 107° F; small, superficial, red spots and papules on skin at site of inoculation; local infiltration of tissues with endothelial leucocytes, swelling of involved epithelial cells; nuclear inclusions present in endothelial leucocytes and some other cells; disease not fatal; virus in circulating blood only during early stages; recovery in a few days without scar formation but with development of specific immunity. The course of the natural disease, presumed to occur in rabbits, is still unknown.

Transmission: Experimentally, by injection of filtrates from diseased tissues; on several occasions also from blood or tissues of apparently normal rabbits.

Serological relationships: Specific neutralizing substances occur in the serum of recovered rabbits.

Immunological relationships: Specific immunity but no cross reactions with vaccinia or herpes viruses.

Thermal inactivation: In 10 minutes at 55° C, but not in 30 minutes at 45° C.

Filterability: Passes Berkefeld V and N filters; passes L_2 filter candle.

Other properties: Viable at least 6

weeks in 50 per cent glycerine and 16 months dried when frozen, and stored on ice.

Literature: Andrewes, Brit. Jour. Exp. Path., *10*, 1929, 188–190, 273–280; Jour. Path. and Bact., *33*, 1930, 301–312; *50*, 1940, 227–234; Rivers and Stewart, Jour. Exp. Med., *48*, 1928, 603–613; Rivers and Tillett, *ibid.*, *39*, 1924, 777–802; *40*, 1924, 281–287; Topacio and Hyde, Am. Jour. Hyg., *15*, 1932, 99–124.

5. **Scelus ulceris** *spec. nov.* From Latin *ulcus*, sore spot.

Common name: Ovine balano-posthitis virus.

Host: *BOVIDAE—Ovis aries* L., sheep.

Geographical distribution: United States, Australia.

Induced disease: In sheep, ulceration with scab production: lesions most severe on prepuce and vulva; in the male, the penis may be involved, usually only with mild inflammation, but if accompanied by paraphimosis there may be extensive ulceration and heavy scab formation.

Transmission: Venereally. Experimentally, by inoculation of prepuce.

Filterability: Passes Berkefeld N and W filters, a 7 lb Mandler candle, and a 3½ per cent collodion membrane.

Literature: Tunnicliff and Matisheck, Science, *94*, 1941, 283–284.

6. **Scelus marmorans** *spec. nov.* From Latin *marmorare*, to marble, in reference to mottling of spleen and liver in host.

Common name: Ectromelia virus.

Hosts: *MURIDAE—Mus musculus* L., white mouse. Esperimentally, also *MURIDAE—Rattus norvegicus* (Berkenhout), rat (infection inapparent). Also, *PHASIANIDAE—Gallus gallus* (L.), chick embryo (12-day-old White Leghorn chick embryo at 36 to 37° C; less satisfactory results at higher temperatures of incubation or in embryos in spring eggs). Derived strains of this virus infect rabbit and guinea pig, not susceptible to original virus from mouse.

Geographical distribution: England.

Induced disease: In white mouse, spleen mottled, liver edges translucent, peritoneal fluid increased in amount; loss of weight; later, cutaneous lesions on foot or elsewhere; affected foot swells, becomes moist, scabbed, then recovers or dries up and separates from the skin at limit of original swelling; in acute disease, death without gross lesions, or, at autopsy, gut dark red, liver dirty gray, soft, bloodless, sometimes mottled, spleen necrotic; inclusion bodies most numerous in lesions of the skin, round or oval, 4 to 13 microns long, without internal differentiation; very young mice probably become infected without developing apparent disease and remain carriers for some time. In rat, inapparent infection; after initial increase of virus, circulating antibodies appear and immunity to reinfection is established.

Transmission: In mouse, by contact. In rat, experimentally, by intranasal inoculation.

Serological relationships: Neutralizing antibodies occur in convalescent mouse serum. Immune sera from the guinea pig specifically agglutinate elementary bodies obtained from infected skin of the white mouse.

Immunological relationships: Recovered mice are solidly immune to many lethal doses.

Thermal inactivation: At 55° C in 30, not in 10, minutes.

Filterability: In broth, passes Mandler, Pasteur-Chamberland L_2, and Berkefeld N filters.

Other properties: Survives drying 6 months, freezing (−10° C) 2 months, 50 per cent glycerine 5 months at least. Resists 1 per cent phenol 20, not 40, days. Size, estimated by filtration, 100 to 150 millimicrons; by ultraviolet-light photography, 130 to 140 millimicrons.

Literature: Barnard and Elford, Proc. Roy. Soc. London, Ser. B, *109*, 1931, 360–380; Baumgartner, Cent. f. Bakt., I Abt., Orig., *133*, 1935, 282–289; Burnet and Lush, Jour. Path. and Bact., *42*, 1936, 469–476; *43*, 1936, 105–120; Jahn, Arch. f. Virusforsch., *1*, 1939, 91–103; Kikuth and

Gönnert, Arch. f. Virusforsch., *1*, 1940, 295–312; Marchal, Jour. Path. and Bact., *33*, 1930, 713–728; McGaughey and Whitehead, *ibid.*, *37*, 1933, 253–256; Paschen, Cent. f. Bakt., I Abt., Orig., *135*, 1936, 445–452.

7. **Scelus bovinum** *spec. nov.* From Latin *bovinus*, of ox, bull, or cow.

Common name: Erosive-stomatitis virus.

Host: *BOVIDAE—Bos taurus* L., domestic cattle. Experimentally, also chorioallantoic membrane of developing hen's egg.

Insusceptible species: *CAVIIDAE—Cavia porcellus* (L.), guinea pig. (In rats, rabbits, mice, sheep, no reaction has been noted after inoculation.)

Geographical distribution: South Africa (Natal); perhaps Ireland (Armagh-disease virus).

Induced disease: In young domestic cattle, lesions on tongue, dental pad, and lips pearl-like at first, then breaking down to form superficial erosions, with white glistening base and red border. Lesions may coalesce to form large, ragged, eroded areas, healing uneventfully with scar formation. No foot lesions; no excessive salivation; no "hotness" of mouth; no systemic disturbances.

Transmission: Spreads slowly, mainly to animals less than three years old, probably by contact. Experimentally, by injection into dental pads, lips, or tongue.

Filterability: Passes Gradocol membrane of about 400 millimicron average pore diameter.

Other properties: Viable after at least 11 days at room temperature, 21 days at refrigerator temperature, 6 weeks frozen and dried in horse-serum saline.

Literature: Mason and Neitz, Onderstepoort Jour. Vet. Sci. and Anim. Indust., *15*, 1940, 159–173.

Genus IV. Hostis *gen. nov.*

Viruses of the Foot-and-Mouth Disease Group, inducing diseases mainly characterized by vesicular lesions. Generic name from Latin *hostis*, enemy or stranger.

The type species is *Hostis pecoris spec. nov.*

Key to the species of genus Hostis.

I. Infecting cattle and other animals with cloven hoofs; horse immune or highly resistant.

1. *Hostis pecoris.*

II. Infecting horse readily.

2. *Hostis equinus.*

1. **Hostis pecoris** *spec. nov.* From Latin *pecus*, cattle.

Common names: Foot-and-mouth disease virus; Virus der Maul- und Klauenseuche.

Hosts: Cow, pig, sheep, goat, reindeer, bison. Experimentally, also guinea pig, rabbit, rat.

Insusceptible species: Chick embryo (chorioallantois); horse (immune or very resistant).

Induced disease: In cow, after incubation period of 2 to 4 days or more, fever, vesicular lesions on tongue, lips, gums, hard palate and feet, soon rupturing; salivation, lameness, generally recovery.

Transmission: Spread rapid, source of infection often obscure; saliva is infective before lesions become obvious.

Thermal inactivation: At 70° C, not at 60° C, in 15 minutes.

Filterability: Passes Seitz, Berkefeld V and N, and Chamberland L_{11} filters.

Strains: Three strains, A, O and C, are immunologically distinct from each other.

Other properties: Particle calculated to be about 20 millimicrons in diameter by centrifugation data, 8 to 12 millimicrons in diameter by filtration; may be separated from mixtures with the larger equine vesicular stomatitis virus by differential filtration. Viable after drying

in vacuo, at least a week at −4 to 0° C. Readily destroyed by 1 to 2 per cent sodium hydrate or above pH 11. Soon inactivated near pH 6.0, but moderately stable at pH 2.0 to 3.0; optimum condition for storage at pH 7.5 to 7.7 in absence of air; return from 3.0 to 7.5 inactivates, however.

Literature: Elford and Galloway, Brit. Jour. Exp. Path., *18*, 1937, 155–161; Galloway and Elford, *ibid.*, *14*, 1933, 400–408; *16*, 1935, 588–613; *17*, 1936, 187–204; Galloway and Schlesinger, Jour. Hyg., *37*, 1937, 463–470; Hare, Jour. Path. and Bact., *35*, 1932, 291–293; Loeffler and Frosch, Cent. f. Bakt., I Abt., *23*, 1898, 371–391; Matte and Sanz, Bull. Soc. Path. Exot., *14*, 1921, 523–529; Olitsky and Boez, Jour. Exp. Med., *45*, 1927, 673–683, 685–699, 815–831, 833–848; Pyl, Ztschr. f. physiol. Chemie, *226*, 1934, 18–28; Pyl and Klenk, Cent. f. Bakt., I Abt., Orig., *128*, 1933, 161–171; Schlesinger and Galloway, Jour. Hyg., *37*, 1937, 445–462.

2. **Hostis equinus** *spec. nov.* From Latin *equinus*, pertaining to horses.

Common names: Vesicular-stomatitis virus, equine vesicular stomatitis virus.

Hosts: Horse, domestic cattle. Experimentally, also guinea pig, swine, white mouse, rabbit (relatively resistant), chick embryo; *Macaca mulatta* (Zimmermann), rhesus monkey; *M. irus*, cynomolgus monkey.

Insusceptible species: Chicken (except embryo).

Geographical distribution: United States (Indiana, New Jersey).

Induced disease: In horse, resembles foot-and-mouth disease of cattle; reddened patches on buccal mucosa, moderate fever, salivation, followed by appearance of vesicles, especially on tongue, filled with clear or yellowish fluid; vesicles often coalesce and soon rupture leaving an eroded surface which heals soon in the absence of complications. Experimentally, in chorioallantois of developing chick embryo, primary lesions involve moderate ectodermal proliferation, degeneration, necrosis; mesodermal inflammation; slight endodermal proliferation.

Serological relationships: Strains isolated in different localities give antisera capable of neutralizing heterologous isolates of virus, but homologous antisera neutralize in higher dilutions than do heterologous antisera.

Immunological relationships: No cross immunity with respect to equine encephalomyelitis virus.

Filterability: Passes Seitz filter.

Other properties: May be separated from mixtures with foot-and-mouth disease virus by propagation on chorioallantoic membrane of chick embryo, which will not support increase of the latter virus. Inactivated by 1:50,000 methylene blue in 2 mm layer 13 cm from 300 candle-power lamp in 60 minutes but not in 20 minutes. Particle estimated on the basis of filtration data to be 70 to 100 millimicrons in diameter; 60 millimicrons in diameter by centrifugation. Not destroyed by acidifying to pH 3 and returning to pH 7.5 (difference from foot-and-mouth disease virus).

Literature: Burnet and Galloway, Brit. Jour. Exp. Path., *15*, 1934, 105–113; Cox and Olitsky, Proc. Soc. Exp. Biol. and Med., *30*, 1933, 653–654; Cox et al., *ibid.*, *30*, 1933, 896–898; Elford and Galloway, Brit. Jour. Exp. Path., *18*, 1937, 155–161; Galloway and Elford, *ibid.*, *14*, 1933, 400–408; *16*, 1935, 588–613; Mohler, Jour. Am. Vet. Med. Assoc., *52*, 1918, 410–422; Olitsky et al., Jour. Exp. Med., *59*, 1934, 159–171; Pyl, Ztschr. f. physiol. Chemie, *226*, 1934, 18–28; Sabin and Olitsky, *ibid.*, *66*, 1937, 15–34, 35–57; *67*, 1938, 201–228, 229–249; Syverton et al., Science, *78*, 1933, 216–217.

Genus V. **Molitor** *gen. nov.*

Viruses of the Wart-Disease Group, inducing diseases mainly characterized by tissue proliferation without vesicle or pustule formation. Generic name from Latin *molitor*, contriver.

The type species is *Molitor verrucae spec. nov.*

Key to the species of genus **Molitor.**

I. Affecting man.
- 1. *Molitor verrucae.*
- 2. *Molitor hominis.*

II. Affecting cow.
- 3. *Molitor bovis.*

III. Affecting dog.
- 4. *Molitor buccalis.*

IV. Affecting chicken.
- 5. *Molitor tumoris.*

V. Affecting rabbit
- 6. *Molitor gingivalis.*
- 7. *Molitor sylvilagi.*
- 8. *Molitor myxomae.*

1. **Molitor verrucae** *spec. nov.* From Latin *verruca*, wart.

Common name: Common-wart virus.

Hosts: *HOMINIDAE—Homo sapiens* L., man. Perhaps also *BOVIDAE—Bos taurus* L., cow. *CANIDAE—Canis familiaris* L., dog.

Induced disease: Experimentally in man, incubation period long, 4 weeks to 6 or more months; initially acanthosis (overgrowth of prickle cell layer of epidermis) and flattening of the papillae; later, interpapillary hypertrophy, inflammation, and marked hyperkeratosis.

Transmission: By contact; in some cases, venereally. Experimentally, by skin scar fication.

Filterability: Passes Berkefeld N filter.

Literature: Ciuffo, Giorn. ital. d. malattie veneree e d. pelle, *48*, 1907, 12–17; Kingery, Jour. Am. Med. Assoc., *76*, 1921, 440–442; Payne, Brit. Jour. Dermat., *3*, 1891, 185–188; Schultz, Deutsch. med. Wchnschr., *34*, 1908, 423; Serra, Giorn. ital. d. malattie veneree e d. pelle, *65*, 1924, 1808–1814; Ullmann, Acta oto-laryngologica, *5*, 1923, 317–334; Wile and Kingery, Jour. Am. Med. Assoc., *73*, 1919, 970–973.

2. **Molitor hominis** *comb. nov.* (*Strongyloplasma hominis* Lipschütz, Arch. Dermat. u. Syph., *107*, 1911, 395.) From Latin *homo*, man.

Common name: *Molluscum contagiosum* virus.

Host: *HOMINIDAE—Homo sapiens* L., man.

Geographical distribution: Perhaps essentially world-wide.

Induced disease: In man, experimentally, prodromal period may be 14 to 50 days, lesions at first like pimples, becoming red, painful, swollen, developing into small tumors covered with stretched and shiny skin; lesions commonest on face, arms, buttocks, back, and sides, healing spontaneously. Inclusions within epithelial cells, known as molluscum bodies, measure 9 to 24 microns in diameter when approximately spherical, 24 to 27 microns in width and 30 to 37 microns in length when elongated; they contain elementary bodies about 0.3 micron in diameter. The outer envelope of the molluscum body is of carbohydrate.

Transmission: By contact. By fomites.

Filterability: Passes Chamberland L_1 and Berkefeld V filters.

Literature: Goodpasture and King, Am. Jour. Path., *3*, 1927, 385–394; Goodpasture and Woodruff, *ibid.*, *7*, 1931, 1–8; Juliusberg, Deutsch. med. Wchnschr.,

31, 1905, 1598–1599; Lipschütz, Arch. Dermat. u. Syph., *107*, 1911, 387–396; in Kolle, Kraus and Uhlenhuth, Handbuch der Pathogenen Mikroorganismen, *8*, 1930, 1031–1040; Van Rooyen, Jour. Path. and Bact., *46*, 1938, 425–436; *49*, 1939, 345–349; Wile and Kingery, Jour. Cutan. Dis., 37, 1919, 431–446.

3. **Molitor bovis** *spec. nov.* From Latin *bos*, cow.

Common name: Cattle-wart virus.

Host: *BOVIDAE—Bos taurus* L., domestic cattle.

Geographical distribution: United States.

Induced disease: In cattle, especially about head, neck, and shoulders in young animals, on udders in cows, affected skin thickened at first, then rough, nodular; warts sometimes become large and pendulous, adversely affecting growth of host; they sometimes become cauliflower-like tumors several inches in diameter; spontaneous regression is not infrequent. Hides from affected animals are reduced in value.

Transmission: Believed to be through injuries to skin when the injured part comes in contact with warty animals or with rubbing posts, chutes, fences, buildings, or other structures with which affected animals have come in contact previously. Experimentally, by skin inoculations, especially in animals under 1 year of age.

Filterability: Passes Berkefeld N filter.

Literature: Creech, Jour. Agr. Res., *39*, 1929, 723–737; U. S. Dept. Agr., Leaflet 75, 1931, 1–4.

4. **Molitor buccalis** *spec. nov.* From Latin *bucca*, cheek.

Common name: Canine oral-papillomatosis virus.

Host: *CANIDAE—Canis familiaris* L., dog.

Insusceptible species: Cat, rabbit, guinea pig, rat, mouse; *Macaca mulatta* (Zimmermann), rhesus monkey.

Induced disease: In young dog, experimentally, about 1 month after inoculation of buccal membrane by scarification, pale, smooth elevations, becoming gradually more conspicuous and roughened; finally a mass of closely packed papillae is formed. Regression with subsequent immunity is frequent; no scars are left on regression. Secondary warts often appear in other parts of the mouth 4 to 6 weeks after primary warts have first been observed.

Transmission: Experimentally by skin scarification.

Serological relationships: Not inhibited by antiserum effective against common-wart virus of man.

Thermal inactivation: At some temperature between 45 and 58° C in 1 hour.

Filterability: Passes Berkefeld N filter.

Other properties: Viable after freezing and drying, if stored dry in icebox, at least 63 days; in storage in equal parts of glycerine and 0.9 per cent NaCl solution at least 64 days.

Literature: DeMonbreun and Goodpasture, Am. Jour. Path., *8*, 1932, 43–56; M'Fadyean and Hobday, Jour. Comp. Path. and Therap., *11*, 1898, 341–344; Penberthy, *ibid.*, *11*, 1898, 363–365.

5. **Molitor tumoris** *spec. nov.* From Latin *tumor*, swelling.

Common names: Fowl-sarcoma virus, Rous chicken-sarcoma virus.

Hosts: *PHASIANIDAE—Gallus gallus* (L.), chicken. Experimentally, also pheasant (serial transfer difficult) and duck (by cell transfer only but filtrates from duck infect injected chicken).

Insusceptible species: Turkey, guinea fowl (both immune to filtrates but capable of supporting tumor line if alternated in a series with common fowl hosts); geese.

Induced disease: In hen, originally found in an adult, pure-bred hen of Barred Plymouth Rock variety. Experimentally transmitted, a circumscribed nodule soon becomes evident at site of implantation; later this becomes necrotic or cystic at its center; as growth enlarges, host becomes emaciated, cold, somnolent, and finally dies; discrete metastases are often found in lungs, heart, and liver. Parent cell of sarcoma is claimed to be

the normal histiocyte, but virus in the affected fowl is not confined to the sarcoma, being widespread in the body in spleen, liver, muscle, brain, etc. In the chick embryo, serial passage is feasible on the egg membrane, in which focal lesions involve only ectodermal tissue.

Transmission: By injection of affected fowl cells or filtrates. Certain transmissible tar-induced sarcomas, not infecting by filtrates, nevertheless induce the formation of antibodies capable of neutralizing this virus. An inhibitor of the virus extracted from tumors appears to be a protein, inactivated at 65° C, but not at 55° C, in 30 minutes and destroyed by trypsin in 3 to 5 hours at pH 8. Oleic acid also may act as an inhibitor. No spontaneous transmission in chickens kept together.

Serological relationships: Particles sedimented by centrifugal force 20,000 to 30,000 times gravity are specifically agglutinated by sera of fowls bearing corresponding tumor. At least one antigen in tumors of hen and duck not in healthy birds; this one fixes complement and gives cross reactions with Rous, Mill Hill 2, Fujinami, and RFD2 tumors. Virus injected into goats produces two antibodies but only one if previously heated; the antibody to the heat-stable constituent requires complement to neutralize virus; the only antibody produced in ducks does not require complement to neutralize.

Thermal inactivation: At or below 54° C in 20 minutes.

Filterability: Passes Berkefeld V and no. 5 (medium) filters.

Other properties: Particle size estimated as about 100 millimicrons (but some say 50 or even 15 millimicrons) in diameter by filtration through graded membranes, about 70 millimicrons (molecular weight 140,000,000) by ultracentrifugation. Contains 8.5 to 9.0 per cent nitrogen, 1.5 per cent phosphorus. Protein tests positive. Feulgen reaction for thymonucleic acid absent; 10 to 15 per cent of the protein may be nucleic acid, probably of ribose type. Pentose present. Virus believed to be of globulin nature or attached to globulin particles (Lewis and Mendelsohn, Am. Jour. Hyg., *12*, 1930, 686–689). Viable indefinitely in dried spleen as in dried sarcoma tissues.

Strains: Several strains have been studied in addition to the original Rous sarcoma no. 1 strain; immunological relationships have been shown between the original strain, the des Ligneris sarcoma strain, the Fujinami sarcoma strain, the fibrosarcoma MH1 and endothelioma MH2 strains; other isolates also have shown serological interrelationships.

Literature: Amies, Jour. Path. and Bact., *44*, 1937, 141–166; Amies et al., Am. Jour. Cancer, *35*, 1939, 72–79; Andrewes, Jour. Path. and Bact., *34*, 1931, 91–107; *35*, 1932, 407–413; *37*, 1933, 17–25, 27–44; *43*, 1936, 23–33; Claude, Jour. Exp. Med., *66*, 1937, 59–72; Science, *87*, 1938, 467–468; *90*, 1939, 213–214; Am. Jour. Cancer, *37*, 1939, 59–63; Claude and Rothen, Jour. Exp. Med., *71*, 1940, 619–633; Dmochowski and Knox, Brit. Jour. Exp. Path., *20*, 1939, 466–472; Elford and Andrewes, *ibid.*, *16*, 1935, 61–66; Gye and Purdy, Jour. Path. and Bact., *34*, 1931, 116–117 (Abst.); Haddow, *ibid.*, *37*, 1933, 149–155; Helmer, Jour. Exp. Med., *64*, 1936, 333–338; Keogh, Brit. Jour. Exp. Path., *19*, 1938, 1–9; Ledingham and Gye, Lancet, *228*, 1935 (*1*), 376–377; Lewis and Mendelsohn, Am. Jour. Hyg., *12*, 1930, 686–689; des Ligneris, Am. Jour. Cancer, *16*, 1932, 307–321; McIntosh, Jour. Path. and Bact., *41*, 1935, 215–217; Mellanby, Jour. Path. and Bact., *46*, 1938, 447–460; *47*, 1938, 47–64; Mendelsohn et al., Am. Jour. Hyg., *14*, 1931, 421–425; Purdy, Brit. Jour. Exp. Path., *13*, 1932, 473–479; Rous, Jour. Exp. Med., *13*, 1911, 397–411.

6. **Molitor gingivalis** *spec. nov.* From Latin *gingiva*, gum.

Common name: Rabbit oral-papillomatosis virus.

Hosts: *LEPORIDAE—Oryctolagus cuniculus* (L.), domestic rabbit. Experimentally, also *Lepus americanus*

Erxleben, snowshoe hare; *L. californicus* Gray, jack rabbit; *Sylvilagus* sp., cottontail rabbit.

Geographical distribution: United States.

Induced disease: In rabbit, benign papillomas, having the form of small, discrete, gray-white, sessile or pedunculated nodules, usually multiple, on lower surface of tongue or, less frequently, on gums or floor of mouth.

Transmission: Perhaps by mother to suckling young, with a latent period before onset of disease. Not highly contagious, if contagious at all, in old animals. Experimentally by puncture of tissues in the presence of virus.

Immunological relationships: Specific immunity develops as a result of disease, but no cross immunity with respect to rabbit-papilloma virus, which differs also in failing to act on oral mucosa.

Filterability: Passes Berkefeld V and N filters.

Literature: Parsons and Kidd, Jour. Exp. Med., *77*, 1943, 233–250.

7. **Molitor sylvilagi** *spec. nov.* From New Latin *Sylvilagus*, generic name of cottontail rabbit.

Common names: Rabbit papilloma or papillomatosis virus, rabbit wart virus.

Hosts: *LEPORIDAE—Sylvilagus* sp., cottontail rabbit. Experimentally, also *LEPORIDAE — Oryctolagus cuniculus* (L.), domestic rabbit.

Geographical distribution: United States.

Induced disease: In cottontail rabbit, at first minute elevations along lines of scarification; later solid masses of wrinkled keratinized tissue, 3 to 4 millimeters in thickness; eventually cornified warts, striated perpendicularly at top, fleshy at base, 1 to 1.5 cm in height; regression rare; natural papillomas become malignant occasionally. In domestic rabbit, experimentally, blood antibody remains low but virus is always masked, preventing serial passage; discrete lesions on skin permit quantitative tests; tarring causes localization of virus from blood stream; papillomas give rise to malignant acanthomatous tumors by graded continuous alteration; metastasis frequent; transplantation to new hosts successful in series; antibody specific for the virus is formed continuously in the transplanted growths although virus is not directly demonstrable by subinoculation from them; malignant growths appear more promptly and frequently where epidermis has been tarred long; virus appears specific for epithelium of skin; growths disappear if treated with X-rays, 3600 r at one time or fractionally; 60 per cent are cured with 3000 r, but 2000 r ineffective.

Transmission: Experimentally, by scarification of skin. Abnormal susceptibility to infection is noted in rabbit skin treated with 0.3 per cent methylcholanthrene in benzene or equal parts of turpentine and acetone.

Serological relationships: Specific neutralization, reversible on dilution. Complement fixation specific, with virus particle as antigen; no cross reaction with antisera for vaccinia, herpes, fibroma, or myxoma viruses. Precipitates occur in properly balanced mixtures of virus and specific antiserum; virus and antibody in both free and neutralized states are present in both soluble and insoluble phases of these suspensions.

Immunological relationships: Intraperitoneal injections immunize specifically. Rabbits immunized to fibroma and myxoma viruses are susceptible to rabbit papilloma virus.

Thermal inactivation: At 70° C, not at 65 to 67°C, in 30 minutes; in 0.9 per cent sodium chloride solution at 65 to 66° C, time not stated.

Filterability: Passes Berkefeld V, N, and W filters; particle size calculated as 23 to 35 millimicrons by filtration as compared with 32 to 50 millimicrons by centrifugation and 44.0 millimicrons by measurement of electron micrographs, which show the particle to be approximately spherical in shape.

Other properties: Infectious particle has sedimentation constant S_{20} = *ca.* 250 × 10^{-13} cm per sec. per dyne; usually there is a secondary boundary at about 375 × 10^{-13}. Isoelectric point between pH 4.8 and 5.1. Maximum absorption at about 2750 Å. Contains thymus nucleic acid about 6.8 to 8.7 per cent; maximum absorption of nucleic acid at about 2630 Å.

Literature: Beard et al., Jour. Inf. Dis., *65*, 1939, 43–52; *69*, 1941, 173–192; Bryan and Beard, *ibid.*, *65*, 1939, 306–321; Friedewald, Jour. Exp. Med., *75*, 1942, 197–220; Hoyle, Jour. Path. and Bact., *50*, 1940, 169–170; Kidd, Jour. Exp. Med., *68*, 1938, 703–724, 725–759; *70*, 1939, 583–604; *71*, 1940, 469–494; *74*, 1941, 321–344; *76*, 1942, 7–20; Kidd and Rous, *ibid.*, *68*, 1938, 529–562; *71*, 1940, 813–838, Kidd et al., *ibid.*, *64*, 1936, 63–77, 79–96; Rous and Beard, *ibid.*, *60*, 1934, 701–722; *62*, 1935, 523–548; Rous and Kidd, *ibid.*, *67*, 1938, 399–428; *71*, 1940, 787–812; Rous et al., *ibid.*, *64*, 1936, 385–400, 401–424; Schlesinger and Andrewes, Jour. Hyg., *37*, 1937, 521–526; Sharp et al., Proc. Soc. Exp. Biol. and Med., *50*, 1942, 205–207; Shope, Jour. Exp. Med., *58*, 1933, 607–624; *65*, 1937, 219–231; Syverton et al., *ibid.*, *73*, 1941, 243–248; Taylor et al., Jour. Inf. Dis., *71*, 1942, 110–114.

8. **Molitor myxomae** (Aragão) *comb. nov.* (*Chlamidozoon myxomae* Aragão, Brazil-Med., *25*, 1911, 471; name later abandoned by its original author in favor of *Strongyloplasma myxomae* Aragão, Mem. Inst. Oswaldo Cruz. *20*, 1927, 231 and 243. The name *Sanarellia cuniculi* Lipschütz, Wien. klin. Wochenschr., *40*, 1927, 1103, was based on the supposed causative organism, defined as varying in size between the size of chlamydozoa and of large cocci; it is not clear whether the structures observed and named were virus particles or not.) From New Latin *myxoma*, a kind of soft tumor, from nature of induced lesion.

Common names: Myxoma virus, *virus myxomatosum*.

Hosts: *LEPORIDAE—Oryctolagus cuniculus* (L.), domestic rabbit. Experimentally, also *Sylvilagus* sp., cottontail rabbit; jack rabbit (once in many trials); *Lepus brasiliensis* (resistant and rarely infected). Also chick embryo and duck embryo.

Insusceptible species: *Lepus californicus* Gray, black-tailed jack rabbit; *L. americanus* Erxleben, varying hare; *Sylvilagus transitionalis* Bangs, cottontail; horse, sheep, goat, cattle, dog (but one reported infected), guinea pig, rat, mouse, fowl, pigeon, duck, cat, hamster, monkey; man (but some conjunctival pain and swelling).

Geographical distribution: South America (Brazil, Uruguay, Argentina), United States (California).

Induced disease: In domestic rabbit, a disease (*myxomatosis cuniculi*) almost always fatal at ordinary room temperatures but not at 36 to 42° C, lesions fewer and regressing after 6 to 8 days at these higher temperatures in most animals. At ordinary temperatures, nodules (edematous tumors) in skin near eyes, nose, mouth, ears, and genitalia; edema of eyelids; conjunctivitis with purulent discharge if skin around eyes is involved. Later marked dyspnea, stertorous breathing, cyanosis, asphyxia. Animals usually die within 1 to 2 weeks of infection. Virus enters bloodstream and invades nervous system at random through walls of blood vessels. Discharges from nose, eyes, and the serous exudates from affected tissues are infectious; urine and feces are not. There are cytoplasmic inclusions in affected epidermal cells. In chick embryo, experimentally, intense inflammation, eventual impairment of circulation and necrosis locally; growth best if embryo is grown at 33 to 35° C and chilled to 25° C for 12 to 18 hours before or after inoculation, lesions being linear and associated with capillaries in ectoderm; virus infects and is recoverable from embryo and depresses hatch.

Transmission: By contact with diseased rabbits or cages recently occupied

by them. Through air for a few inches. Rarely by feeding. Experimentally, by rubbing conjunctiva with a bit of infected tissue or with a platinum loop contaminated from diseased conjunctiva; has been recovered from flies. By injection. By flea, *Ctenopsylla felis* (*PULICIDAE*), rarely.

Serological relationships: An attack of the disease induces the formation of neutralizing antibodies. Cross neutralization by antisera to myxoma and fibroma strains. Complement is fixed with myxoma virus as test antigen in the presence of antisera to myxoma or fibroma strains. Serum of rabbit inoculated with a soluble antigen, a heat-labile protein with isoelectric point near pH 4.5, agglutinates myxoma elementary bodies. A second soluble antigen, also heat labile, appears distinct, inhibiting its own antibody even after inactivation of its precipitating power by exposure at 56° C.

Immunological relationships: Myxoma-recovered domestic rabbits become immune to reinfection; fibroma-strain-recovered animals, although partially immunized, still support myxoma-strain virus introduced into the testicle. Heat-inactivated virus (60° C for 30 minutes) tends to immunize if given intradermally; there is then an allergic local response, less severe generalized disease, delayed death or recovery. If fibroma virus precedes myxoma virus by 48 to 96 hours, there is marked protection.

Thermal inactivation: At 55° C in 10 minutes; at 50° C in 1 hour. A substance thermostabile for 30 minutes at 60 to 75° C, but not at 90° C, is itself unable to produce myxomatous changes after the heat treatment but may do so in combination with fibroma virus, and transmissible myxoma virus is then reconstituted. Although it is supposed by some that this indicates the transformation of fibroma-strain virus into myxoma-strain virus, the possibility that heat-modified myxoma-strain virus is reactivated has not been eliminated.

Filterability: Passes Berkefeld V and N filters; not Chamberland L_5 or L_7 filters.

Other properties: Inactivated above pH 12.0 and below pH 4.0. Withstands drying. Viable at least 3 months at 8 to 10° C.

Literature: Aragão, Brazil-med., *25*, 1911, 471; Mem. Inst. Oswaldo Cruz, *20*, 1927, 225–235; Berry and Dedrick, Jour. Bact., *31*, 1936, 50–51 (Abst.); Berry and Lichty, *ibid.*, *31*, 1936, 49–50 (Abst.); Berry et al., Second International Congress for Microbiology, Report of Proceedings, London, 1936, 96 (Abst.); Fisk and Kessel, Proc. Soc. Exp. Biol. and Med., *29*, 1931, 9–11; Gardner and Hyde, Jour. Inf. Dis., *71*, 1942, 47–49; Hobbs, Am. Jour. Hyg., *8*, 1928, 800–839; Science, *73*, 1931, 94–95; Hoffstadt and Omundson, Jour. Inf. Dis., *68*, 1941, 207–212; Hoffstadt and Pilcher, Jour. Bact., *35*, 1938, 353–367; *39*, 1940, 40–41; Jour. Inf. Dis., *64*, 1939, 208–216; *65*, 1939, 103–112; Hoffstadt et al., *ibid.*, *68*, 1941, 213–219; K. E. Hyde, Am. Jour. Hyg., *23*, 1936, 278–297; R. R. Hyde, *ibid.*, *30* (B), 1939, 37–46, 47–55; Hyde and Gardner, *ibid.*, *17*, 1933, 446–465; *30*, (B), 1939, 57–63; Kessel et al., Proc. Soc. Exp. Biol. and Med., *28*, 1931, 413–414; Lipschütz, Wien. klin. Wchschr., *40*, 1927, 1101–1103; Lush, Austral. Jour. Exp. Biol. and Med. Sci., *15*, 1937, 131–139; *17*, 1939, 85–88; Martin, Austral. Counc. Sci. and Indust. Res., Bull. 96, 1936, 28 pages; Moses, Mem. Inst. Oswaldo Cruz, *3*, 1911, 46–53; Parker and Thompson, Jour. Exp. Med., *75*, 1942, 567–573; Plotz, Compt. rend. Soc. Biol., Paris, *109*, 1932, 1327–1329; Rivers, Jour. Exp. Med., *51*, 1930, 965–976; Rivers and Ward, *ibid.*, *66*, 1937, 1–14; Rivers et al., *ibid.*, *69*, 1939, 31–48; Sanarelli, Cent. f. Bakt., I Abt., *23*, 1898, 865–873; Shaffer, Am. Jour. Hyg., *34* (B), 1941, 102–120; Shope, Jour. Exp. Med., *56*, 1932, 803–822; Smadel et al., *ibid.*, *72*, 1940, 129–138; Splendore, Cent. f. Bakt., I Abt., Orig., *48*, 1909, 300–301; Stewart, Am. Jour. Cancer, *15* Suppl.,

1931, 2013–2028; Swan, Austral. Jour. Exp. Biol. and Med. Sci., *19*, 1941, 113–115.

Strains and substrains: A strain from cottontail rabbits (*Sylvilagus sp.*), differing from typical myxoma virus, has been studied extensively under the name fibroma virus. This strain in turn is recognized as consisting of variants and has been investigated as typical (OA) and inflammatory (IA) substrains, antigenically alike but the latter tending to generalize in domestic rabbits. Fibroma virus is not lethal in domestic rabbits as the type strain almost always is; it appears to lack some antigenic constituents, inducing the formation of agglutinins that give cross reactions with the type but of neutralizing and complement-fixing antibodies that do not. The fibroma strain does not generally appear in the blood stream, as myxoma virus does, and is not contagious, at least it does not spread spontaneously among domestic rabbits as the myxoma strain does; the manner of its spread in wild rabbits in nature is not known. Its particle size has been calculated as 126 to 141 millimicrons by centrifugation, 125 to 175 millimicrons by filtration. (Ahlström, Jour. Path. and Bact., *46*, 1938, 461–472; Andrewes, Jour. Exp. Med., *63*, 1936, 157–172; Hoffstadt and Pilcher, Jour. Inf. Dis., *68*, 1941, 67–72; Hurst, Brit. Jour. Exp. Path., *18*, 1937, 1–30; Austral. Jour. Exp. Biol. and Med. Sci., *16*, 1938, 53–64, 205–208; Hyde, Am. Jour. Hyg., *24*, 1936, 217–226; Ledingham, Brit. Jour. Exp. Path., *18*, 1937, 436–449; van Rooyen, *ibid.*, *19*, 1938, 156–163; van Rooyen and Rhodes, Cent. f. Bakt., I Abt., Orig., *142*, 1938, 149–153; Schlesinger and Andrewes, Jour. Hyg., *37*, 1937, 521–526; Shope, Jour. Exp. Med., *56*, 1932, 793–822; *63*, 1936, 33–41, 43-57, 173–178.

FAMILY III. ERRONACEAE *FAM. NOV.*

Viruses of the Encephalitis Group, inducing diseases mainly characterized by effects on nerve tissues.

Key to the genera of family **Erronaceae.**

I. Viruses of the Typical Encephalitis Group.
   Genus I. *Erro*, p. 1248.
II. Viruses of the Poliomyelitis Group
   Genus II. *Legio*, p. 1257.
III. Viruses of the Rabies Group.
   Genus III. *Formido*, p. 1263.

Genus I. **Erro** *gen. nov.*

Viruses of the Typical Encephalitis Group, inducing diseases mainly characterized by injuries to cells of the brain. Vectors of some known to be ticks; dipterous insects may also transmit. Generic name from Latin *erro*, a vagrant.

The type species is *Erro scoticus spec. nov.*

Key to the species of genus **Erro.**

I. Affecting sheep principally, but also man.
   1. *Erro scoticus.*
II. Affecting man principally.
   2. *Erro silvestris.*
   3. *Erro incognitus.*
   4. *Erro japonicus.*
   5. *Erro nili.*
   6. *Erro scelestus.*
III. Affecting horse principally, but also man.
   7. *Erro equinus.*
IV. Affecting horse, cow, sheep.
   8. *Erro bornensis.*

1. **Erro scoticus** *spec. nov.* From Latin *Scoticus*, Scottish.

Common name: Louping-ill virus.

Hosts: *BOVIDAE—Ovis aries* L., sheep. *HOMINIDAE—Homo sapiens* L., man. Experimentally, also mouse, rat (subclinical infection), chick embryo (discrete primary lesions on chorioallantoic membrane), *Macacus rhesus*, horse, cow, pig.

Insusceptible species: Guinea pig, rabbit.

Geographical distribution: Scotland, northern England.

Induced disease: In sheep, encephalitis characterized by dullness followed by incoordination of movement, frequently with tremors chiefly of the head; salivation, champing of jaws; prostration, coma, death. In man, encephalitis with prompt and complete recovery accompanied by formation of specific neutralizing antibodies. In mouse, experimentally, diffuse encephalomyelitis with mild meningeal involvement; following intracerebral inoculation, fine rhythmical tremor involving neck, nose, and ears, unsteadiness, muscle spasms, respiratory distress, sometimes clonic and rarely tonic convulsions; hind limb paralysis, dribbling of urine, cessation of spontaneous limb movements, death; in mouse inoculated intraperitoneally, virus usually enters central nervous system by way of the olfactory mucosa and olfactory bulb, occasionally by trauma at points of

damage; in mouse inoculated intranasally, virus enters blood and reaches the olfactory bulb where it multiplies to a high concentration before infecting the remainder of the brain and the rest of the nervous system; tends to disappear from the blood after sickness begins but persists in the brain until death from encephalitis. In chick embryo, after inoculation of chorioallantoic membrane, edema and opacity spreading from site of inoculation on membrane of 10-day embryo; in 12-day eggs, discrete primary lesions, sometimes with secondary lesions surrounding them on the inoculated membrane; embryo dies in about 6 days, after showing jaundice, edema, mottling of the liver with necrosis; virus regularly in blood. In monkey, *Macacus rhesus*, progressive cerebellar ataxia; encephalomyelitis with involvement and massive destruction of Purkinje cells in the cerebellum.

Transmission: By ticks, *Rhipicephalus appendiculatus* and *Ixodes ricinus* (*IXODIDAE*). In *Rhipicephalus appendiculatus*, the larva or nymph becomes infected; only a few individuals retain virus until the adult stage; virus does not pass through the egg. Non-viruliferous ticks do not acquire virus by feeding with infective ticks on immune animals. Experimentally, by intracerebral or intraperitoneal injection in mouse; by intranasal instillation in rat, mouse, and monkey.

Serological relationships: Complement fixation and neutralization tests show cross reactions with Russian spring-summer encephalitis virus, but immune serum against louping-ill virus is only partially effective in neutralizing the spring-summer encephalitis virus.

Immunological relationships: Mice are protected against louping-ill virus by vaccination with non-virulent spring-summer encephalitis virus but protection is less effective than for the homologous virus. No cross immunity with respect to Rift Valley fever virus or poliomyelitis virus in *Macacus rhesus*, but immunity with respect to reinfection by louping-ill virus has been demonstrated.

Thermal inactivation: At 58° C in 10 minutes.

Filterability: Passes Berkefeld V, N, and W filters.

Other properties: Viable in broth filtrates after storage at 4° C and pH 7.6 to 8.5 for 70 days. Particle diameter, calculated from ultrafiltration data, 15 to 20 millimicrons.

Literature: Alexander and Neitz, Vet. Jour., *89*, 1933, 320–323; Onderstepoort Jour. Vet. Sci. and Anim. Industr., *5*, 1935, 15–33; Alston and Gibson, Brit. Jour. Exp. Path., *12*, 1931, 82–88; Burnet, Jour. Path. and Bact., *42*, 1936, 213–225; Brit. Jour. Exp. Path., *17*, 1936, 294–301; Burnet and Lush, Austral. Jour. Exp. Biol. and Med. Sci., *16*, 1938, 233–240; Casals and Webster, Science, *97*, 1943, 246–248; Jour. Exp. Med., *79*, 1944, 45–63; Elford and Galloway, Jour. Path. and Bact., *37*, 1933, 381–392; Findlay, Brit. Jour. Exp. Path., *13*, 1932, 230–236; Fite and Webster, Proc. Soc. Exp. Biol. and Med., *31*, 1934, 695–696; Galloway and Perdrau, Jour. Hyg., *35*, 1935, 339–346; Hurst, Jour. Comp. Path. and Therap., *44*, 1931, 231–245; M'Fadyean, Jour. Comp. Path. and Therap., 7, 1894, 207–219; *13*, 1900, 145–154; Pool et al., *ibid.*, *43*, 1930, 253–290; Rivers and Schwentker, Jour. Exp. Med., *59*, 1934, 669–685; Schwentker et al., *ibid.*, *57*, 1933, 955–965.

2. **Erro silvestris** *spec. nov.* From Latin *silvestris*, of the forest, in reference to incidence of the induced disease almost exclusively in those who enter forest lands.

Common names: Spring-summer encephalitis virus, forest spring encephalitis virus.

Hosts: Man; probably cattle, horse; *Eutamias asiaticus orientalis*, *Evotomys rufocanus arsenjevi*. Experimentally, also white mouse, *Macacus rhesus*, birds, goat, sheep, *Microtus michnoi pelliceus* Thom., *Cricetulus furunculus*.

Geographical distribution: Union of Soviet Socialist Republics.

Induced disease: In man, acute non-suppurative encephalitis, abrupt onset, steep rise of temperature to 38 to 40° C, severe headache, giddiness, and vomiting; pareses and paralyses of upper or lower limbs or muscles of neck and back; residual atrophic paralyses common; mortality among cases, 30 per cent; 80 per cent of all cases occur in May and June.

Transmission: By tick, *Ixodes persulcatus* (*IXODIDAE*); the virus seems to hibernate in this species and has proved capable of passing through eggs to progeny. Experimentally, also by ticks *Dermacentor silvarum* and *Haemaphysalis concinna* (*IXODIDAE*).

Serological relationships: Virus-neutralizing antibodies, found without other evidence of disease in some men and in many cattle and horses, believed to indicate susceptibility of these hosts to latent infections. No cross neutralization with St. Louis encephalitis virus. Japanese summer encephalitis virus is in part antigenically related, but some antigenic constituents of this virus are missing in spring-summer encephalitis virus and *vice versa*.

Immunological relationships: Formolized virus immunizes specifically.

Filterability: Passes Berkefeld and Chamberland filter candles.

Literature: Smorodintseff, Arch. f. gesamt. Virusforsch., *1*, 1940, 468–480; Soloviev, Acta Med. U. R. S. S., *1*, 1938, 484–492 (Biol. Abst., *17*, 1943, 1726, no. 18777).

3. **Erro incognitus** *spec. nov.* From Latin *incognitus*, unknown, in reference to mystery surrounding the nature and relationships of this virus, as evidenced by common name.

Common name: Australian X-disease virus.

Hosts: *HOMINIDAE—Homo sapiens* L., man. Experimentally, also sheep, horse, cow, rhesus monkey.

Geographical distribution: Australia.

Induced disease: In man, polioencephalitis, especially in children, occurring in late summer; mortality high; characterized by headache, body pains, drowsiness, weakness, then vomiting, fever, convulsions; paralysis of limbs, eye-muscles, or face rare; recovery rapid in non-fatal cases.

Literature: Kneebone, Austral. Jour. Exp. Biol. and Med. Sci., *3*, 1926, 119–127; Perdrau, Jour. Path. and Bact., *42*, 1936, 59–65.

4. **Erro japonicus** *spec. nov.* From New Latin *Japonia*, Japan.

Common name: Japanese B encephalitis virus.

Hosts: *HOMINIDAE—Homo sapiens* L., man. Experimentally, also young sheep, mouse, and *Macacus rhesus*.

Geographical distribution: Japan, Union of Soviet Socialist Republics.

Induced disease: In man, loss of appetite, drowsiness, nausea, then rapid rise of temperature, pains in joints and chest; restlessness followed by apathy, coma; death, usually before end of second week, or recovery, sometimes with persistence of evidences of damage done to the nervous system by the disease.

Serological relationships: Specific antiserum does not neutralize St. Louis encephalitis virus or louping-ill virus. Russian autumn-encephalitis virus induces the formation of antisera neutralizing Japanese B encephalitis virus. Russian spring-summer encephalitis virus contains some, but not all, antigens in common with this virus. Australian X-disease virus is distinct in neutralization tests.

Immunological relationships: Specific immunity as a result of earlier infection in mice; no cross protection with respect to St. Louis encephalitis virus. Vaccination with Japanese B encephalitis virus does not enhance resistance to West Nile encephalitis virus but only to the homologous virus.

Thermal inactivation: At 56° C in 30 minutes.

Filterability: Passes Berkefeld N, W, Chamberland L_2, L_3, and Seitz EK filters, with ease.

Literature: Kudo et al., Jour. Immunol., *32*, 1937, 129–135; Smorodintseff et al., Arch. f. gesamt. Virusforsch., *1*, 1940, 550–559; Webster, Jour. Exp. Med., *67*, 1938, 609–618.

5. **Erro nili** *spec. nov.* From Latin *Nilus*, god of the Nile.

Common name: West Nile encephalitis virus.

Hosts: *HOMINIDAE—Homo sapiens* L., man (perhaps without inducing any definite disease). Experimentally, also rhesus monkey, mouse.

Geographical distribution: Africa (Uganda).

Induced disease: In man, no details are known; virus was originally isolated from blood of a woman native of Uganda; at the time the temperature of the patient was 100.6° F but she denied illness; moreover, two laboratory workers developed neutralizing antibodies without recognizable clinical disease. In mouse, experimentally, after intracerebral inoculation, incubation period to 4 or 5 days, then hyperactivity and roughening of coat; later, weakness, hunched attitude, sometimes paralysis of hind quarters; usually coma before death. In rhesus monkey, experimentally, after intracerebral or intranasal inoculation, fever and encephalitis.

Serological relationships: No cross reactions in complement fixation tests between this and equine encephalitis virus, Japanese B encephalitis virus, St. Louis encephalitis virus, or lymphocytic choriomeningitis virus. Neutralization tests show some common antigens in West Nile encephalitis virus, Japanese B encephalitis virus and St. Louis encephalitis virus; antiserum to West Nile virus does not neutralize either of the others but antisera against St. Louis virus may neutralize West Nile virus and antisera against Japanese B virus have some effectiveness in neutralizing both West Nile virus and St. Louis virus.

Immunolcgical relationships: Vaccination with this virus dces not enhance resistance to Japanese B or St. Louis encephalitis viruses but only resistance to the homolcgous virus.

Thermal inactivation: At 55° C, not at 50° C, in 30 minutes.

Filterability: Passes Berkefeld V, N, and W filter candles readily; also passes Seitz EK asbestos pads and collodion membranes 79, not 62, millimicrons in average pore diameter.

Other properties: Infective particle 21 to 31 millimicrons in diameter, as calculated from filtration experiments. Viable at least 2 weeks at 2 to 4° C. Viable after drying from the frozen state.

Literature: Havens et al., Jour. Exp. Med., *77*, 1943, 139–153; Smithburn, Jour. Immunol., *44*, 1942, 25–31; Smithburn et al., Am. Jour. Trop. Med., *20*, 1940, 471–492.

6. **Erro scelestus** *spec. nov.* From Latin *scelestus*, infamous.

Common name: St. Louis encephalitis virus.

Hosts: *HOMINIDAE—Homo sapiens* L., man. A great number of mammals and birds in endemic areas may have antisera that neutralize the virus, indicating that they are probably natural hosts; among these are: *ANATIDAE—Anas platyrhyncha* L., Mallard and Pekin ducks; *Anser anser* (L.), domestic goose. *BOVIDAE—Bos taurus* L., cow; *Capra hircus* L., goat; *Ovis aries* L., sheep. *CANIDAE—Canis familiaris* L., dog. *COLUMBIDAE—Columba livia*, domestic pigeon; *Zenaidura macroura*, western mourning dove. *EQUIDAE—Equus caballus* L., horse. *FALCONIDAE—Falco sparverius* L., sparrow hawk. *LEPORIDAE—Lepus californicus* Gray, jack rabbit; *Sylvilagus nuttalli*, cottontail rabbit. *MELEAGRIDAE—Meleagris gallopavo* L., turkey. *MURIDAE—Rattus norvegicus* (Berkenhout), brown

rat. *MUSCICAPIDAE*—*Turdus migratorius* L., robin. *PHASIANIDAE*—*Gallus gallus* (L.), chicken; *Lophortyx californica*, California quail. *PICIDAE*—*Asyndesmus lewis*, Lewis woodpecker; *Colaptes cafer* (Gm.), red-shafted flicker. *STRIGIDAE*—*Bubo virginianus* (Gm.), great horned owl. *SUIDAE*—*Sus scrofa* L., pig. Experimentally, white mouse (some substrains of the Swiss white mouse are genetically more readily infected than others); *Macacus rhesus*; pigeon (inapparent infection); chick embryo and to a limited extent the young hatched chick.

Insusceptible species: Laboratory rabbit, *Cebus* monkey, guinea pig, rat.

Geographical distribution: United States.

Induced disease: In man, during summer and fall, about 9 to 21 days after exposure, headache, high fever, rigidity of neck, tremors; encephalitis, usually with fever; some patients become drowsy, others sleepless or delirious; usual sequelae headaches, irritability, some loss of memory, and drowsiness; neutralizing antibodies maintained *in vivo* at least 2½ years after occurrence of disease. Experimentally, in susceptible strains of white mouse inoculated by intracerebral injection, after 3 to 4 days, coarse tremors, convulsions, prostration, death; perivascular accumulations of mononuclear leucocytes throughout brain, stem, cord, and pia, with destruction of pyramidal cells in the *lobus piriformis* and *cornu Ammonis*; subcutaneous and intraperitoneal injections immunize against subsequent infection by intracerebral inoculation, virus reaching only blood and spleen in the process of immunization unless an excessive dose is given; some substrains of the White Swiss mouse are relatively resistant to infection, requiring inoculation with about 1000 times the minimal infective dose for highly susceptible strains and when infected proving relatively poor sources of virus for subinoculation; highly susceptible substrains of the White Swiss mouse lack a single major, dominant, genetic factor that is present in resistant substrains.

Transmission: By mosquito, *Culex tarsalis* Coquillett (*CULICIDAE*), probably extensively; this insect has been collected in nature carrying the virus. Experimentally, by larvae of American dog tick, *Dermacentor variabilis* (Say) (*IXODIDAE*); by mosquito, *Culex pipiens* Linn., var. *pallans* Coq. (*CULICIDAE*). To mice, by feeding on infected tissues.

Serological relationships: Human antisera may neutralize virus after clinical and subclinical attacks.

Immunological relationships: Specific intracerebral immunity after vaccination by subcutaneous or intraperitoneal injection in mice appears early (about 1 week after vaccination) and disappears before humoral antibody titer reaches its maximum.

Thermal inactivation: At 56° C in 30 minutes.

Filterability: Passes Berkefeld V and N filter candles and collodion membranes 66 millimicrons in average pore diameter.

Other properties: Storage in human brain tissue in glycerine inactivates this virus in about 32 days. Diameter of infective particle calculated from filtration data as about 20 to 33 millimicrons. In storage, rabbit and sheep sera act to some extent as preservatives. At 4° C, after drying *in vacuo* while frozen, viable in apparently undiminished titer for at least 17 months.

Literature: Bang and Reeves, Jour. Inf. Dis., *70*, 1942, 273–274; Bauer et al., Proc. Soc. Exp. Biol. and Med., *31*, 1934, 696–699; Blattner and Cooke, Jour. Inf. Dis., *70*, 1942, 226–230; Blattner and Heys, Proc. Soc. Exp. Biol. and Med., *48*, 1941, 707–710; Cook, Jour. Inf. Dis., *63*, 1938, 206–216; Cook and Hudson, *ibid.*, *61*, 1937, 289–292; Elford and Perdrau, Jour. Path. and Bact., *40*, 1935, 143–146; Hammon and Howitt, Am. Jour. Hyg., *35*, 1942, 163–185; Hammon et al., Science, *94*, 1941, 305–307, 328–330; Jour. Inf. Dis., *70*, 1942, 263–266, 267–272, 278–

283; Harford and Bronfenbrenner, Jour. Inf. Dis., *70*, 1942, 62–68; Harrison and Moore, Am. Jour. Path., *13*, 1937, 361–375; Hodes, Jour. Exp. Med., *69*, 1939, 533–543; Hodes and Webster, *ibid.*, *68*, 1938, 263–271; Lennette and Smith, Jour. Inf. Dis., *65*, 1935, 252–254; Mitamura et al., Trans. Soc. Path. Jap., *27*, 1937, 573–580; Muckenfuss *et al.*, U. S. Pub. Health Service, Public Health Rept., 48, 1933, 1341–1343; O'Leary et al., Jour. Exp. Med., *75*, 1942, 233–246; Reeves et al., Proc. Soc. Exp. Biol. and Med., *50*, 1942, 125–128; Sulkin et al., Jour. Inf. Dis., *67*, 1940, 252–257; Webster, Jour. Exp. Med., 65, 1937, 261–286; *68*, 1938, 111–124; Webster and Clow, *ibid.*, *63*, 1936, 433–448, 827–845; Webster and Fite, *ibid.*, *61*, 1935, 103–114, 411–422; Webster and Johnson, *ibid.*, *74*, 1941, 489–494; Webster et al., *61*, 1935, 479–487; *62*, 1935, 827–847.

7. **Erro equinus** *spec. nov.* From Latin *equinus*, pertaining to horses.

Common name: Equine encephalitis virus.

Hosts: *EQUIDAE—Equus caballus* L., horse; F_1 hybrid of the horse and *E. asinus* L., mule. *HOMINIDAE—Homo sapiens* L., man. *COLUMBIDAE—Columba livia*, domestic pigeon. *PHASIANIDAE*—ring-necked pheasant. *TETRAONIDAE—Tympanuchus cupido* L., var. *americanus* (Reichenbach), prairie chicken. Many additional species have been found to show neutralizing antisera at times and these are presumably natural hosts of the virus upon occasion; among them are: *ANATIDAE—Anas platyrhyncha* L., Mallard and Pekin ducks; *Anser anser* (L.), domestic goose. *BOVIDAE—Bos taurus* L., cow; *Capra hircus* L., goat; *Ovis aries* L., sheep. *CANIDAE—Canis familiaris* L., dog. *CHARADRIIDAE—Oxyechus vociferus* L., killdeer. *CRICETIDAE—Microtus montanus* (Peale), field mouse; *Peromyscus maniculatus* (Wagner), white-footed mouse. *FALCONIDAE—Falco sparverius* L., sparrow hawk. *MELEAGRIDAE—Meleagris gallopavo* L., turkey. *MURIDAE—Rattus rattus* L., black rat. *MUSCICAPIDAE—Turdus migratorius* L., robin. *MUSTELIDAE—Mustela frenata* Lichtenstein, weasel. *PHASIANIDAE—Gallus gallus* (L.), chicken; *Lophortyx californica*, California quail; *Phasianus colchicus* L., ring-necked pheasant. *PICIDAE—Colaptes cafer* (Gm.), red-shafted flicker. *STRIGIDAE—Bubo virginianus* (Gm.), great horned owl. *SUIDAE—Sus scrofa* L., pig. Experimentally, also chick embryo, goose embryo, pheasant embryo, robin embryo, pigeon embryo, turkey embryo, sparrow embryo, duck embryo, and guinea-fowl embryo; white mouse, guinea pig, rabbit, pigeon, white rat, calf, sheep, monkey, goat, dog, hen, turkey; *Zonotrichia leucophrys gambeli*, Gambel sparrow; *Passer domesticus* L., English sparrow; *Lophortyx californica*, quail; *Junco oreganus*, junco; *Toxostoma lecontei lecontei*, thrasher; *Citellus richardsonii* (Sabine), gopher or Richardson's ground squirrel; *Sigmodon hispidus* Say and Ord, cotton rat; *Dipodomys heermanni* Le Conte, kangaroo rat; *Reithrodontomys megalatus*, wild mouse; *Microtus montanus*, *M. californicus* and *M. mordax*, wild mice; *Peromyscus maniculatus* (Wagner), white-footed mouse; *Neotoma fuscipes* Baird, wood rat; *Sylvilagus bachmani* (Waterhouse), brush rabbit; *S. audubonii* (Baird), cottontail rabbit; *Canis familiaris* L., dog (puppies); *Anser cinereus*, goose; *Anas boscas* L., duck; *Circus rufus* (Gm.), hawk; *Turdus merula* L., blackbird; *Ciconia ciconia* L., white stork; *Vultur fulvus* Briss., tawny vulture; *Marmota monax* (L.), woodchuck; *Microtus pennsylvanicus* (Ord.), field vole; *Speotyto cunicularia hypugaea* (Bonaparte), western burrowing owl; *Molothrus ater* (Boddaert), cowbird; common quail or bob-white.

Insusceptible species: Frog (cat and opossum reported as "refractory").

Geographical distribution: United States, Canada, Argentina.

Induced disease: In horse, initial fever, then signs of fatigue, somnolence; occa-

sional excitability followed by incoordinated action of limbs, disturbed equilibrium, grinding of teeth, paresis and varied paralyses; frequently inability to swallow, paralysis of lips and bladder, amaurosis; case fatality about 50 per cent; recovery without sequelae in mild cases; death within 3 to 8 days in severe cases. In man (children particularly vulnerable), a profound, acute, disseminate and focal encephalomyelitis characterized by intense vascular engorgement, perivascular and parenchymatous cellular infiltration and extreme degenerative changes in the nerve cells. In chick embryo, excessive increase of virus continuing until just before host's death, virus being found eventually throughout the egg but most concentrated in the embryo; vaccines made from virus grown in chick embryo and then inactivated are especially effective because of the high titer of virus represented in them; increased resistance with age characteristic of chorioallantoic membrane as well as of hatched chick; rounded acidophilic masses occur usually near periphery of nucleus in embryonic nerve cells; no such inclusions are found as a result of infection with Borna disease virus or poliomyelitis virus.

Transmission: Experimentally by tick, *Dermacentor andersoni* Stiles (*IXODIDAE*), passing through eggs to offspring; this tick is infective to susceptible animals on which it feeds as larva, nymph or adult. Experimentally by *Aëdes aegypti* L. (to guinea pig and horse, preinfective period 4 to 5 days; insects retain virus for duration of life; not to eggs of infected mosquitoes; not passed from males to females or by males from female to female), *A. albopictus*, *A. atropalpus*, *A. cantator*, *A. dorsalis*, *A. nigromaculis*, *A. sollicitans*, *A. taeniorhynchus*, *A. triseriatus*, and *A. vexans* (*CULICIDAE*). *Triatoma sanguisuga* (Le Conte) (*REDUVIIDAE*) has been found infected in nature and has transmitted virus experimentally to guinea pigs. The American dog tick, *Dermacentor variabilis* Say (*IXODIDAE*) has been infected by inoculation, not by feeding; it has not been shown to transmit.

Serological relationships: Neutralizing antibodies are formed as a result of vaccination with inactive, formolized virus; antigenicity of formalin-inactivated virus as well as of active virus is blocked in the presence of antiserum. In rabbit, cerebral resistance is coincident with presence of neutralizing antibody in spinal fluid. In guinea pig, therapy with specific antiserum ineffective if begun after onset of encephalitis; effective if begun within 24 to 48 hours of peripheral inoculation. No cross neutralization reaction with lymphocytic choriomeningitis virus, Japanese B encephalitis virus or St. Louis encephalitis virus. Constituent strains (typical Western and Eastern) do not give cross neutralization reactions, but do show the presence of common antigens by cross reactions in complement fixation not shared with such other viruses as Japanese B encephalitis virus, St. Louis encephalitis virus, West Nile encephalitis virus, lymphocytic choriomeningitis virus. Sera of human cases may be negative by complement fixation tests a few days after onset, yet strongly strain-specific during second week of illness.

Immunological relationships: Young of immunized guinea pigs are immune to homologous strain at least a month after birth. No cross immunity between Western and Eastern strains of equine encephalitis virus.

Thermal inactivation: At 60° C, not at 56° C, in 10 minutes.

Filterability: Passes collodion membranes 66, not 60, millimicrons in average pore diameter. Passes Berkefeld V, N, and W, finest Mandler, and Seitz filters.

Other properties: Inactivated below pH 5.5. Viable at least a year, dry in vacuum. Particle diameter estimated from filtration experiments to be 20 to 30 millimicrons. Electron micrographs show particles as spherical or disk-shaped, about 39 millimicrons in diameter with round or oval region of high density within each; older preparations show

comma-shaped particles. Sedimentation constant, mean $265.5 \times 10^{-13} \pm 5.4 \times 10^{-13}$ (range 252 to 276×10^{-13}). Specific volume 0.864. Molecular weight of liponucleoprotein complex behaving as the virus calculated as 152 million, approximately 250 particles giving 50 per cent infection; material contains 4 per cent carbohydrate. Absorption of ultraviolet light reaches a peak at about 2600 Å., a broad minimum at about 2450 Å., and an increase at 2200 Å.

Strains: The Western strain (so-called Western equine encephalitis virus) may be considered as type of a large group of variants met in nature; some produce clinically milder disease than others (Birch, Am. Jour. Vet. Res., *2*, 1941, 221–226); they may change in virulence on passage in experimental hosts. The Eastern strain (so-called Eastern equine encephalitis virus) has been studied extensively also, and has been found to differ from the type strain especially: in more rapid course of induced disease in the horse; in being experimentally transmissible to sheep, pig, dog, cat and the European hedgehog; in its localization in eastern coast states and absence from the area between California and Wisconsin, where the type strain is found; in failure experimentally to infect *Aëdes aegypti* unless inoculated into body cavity by needle puncture, whereupon it persists and can be transmitted; and in failure of cross-neutralization with the western strain. A strain produced by serial passage in pigeons is reported to have caused no obvious reaction in horses but to have induced the formation of neutralizing antibodies. A Venezuelan strain differs from the type in complement-fixation reactions; it induces in man a mild disease, characterized by malaise, fever, headache or drowsiness, and uneventful recovery (Casals et al., Jour. Exp. Med., *77*, 1943, 521–530).

Literature: Bang, Jour. Exp. Med., *77*, 1943, 337–344; Bauer et al., Proc. Soc. Exp. Biol. and Med., *33*, 1935, 378–382; Beard et al., Science, *87*, 1938, 490; Birch, Am. Jour. Vet. Res., *2*, 1941, 221–226; Casals and Palacios, Science, *94*, 1941, 330; Covell, Proc. Soc. Exp. Biol. and Med., *32*, 1934, 51–53; Cox, *ibid.*, *33*, 1936, 607–609; Cox and Olitsky, Jour. Exp. Med., *63*, 1936, 745–765; *64*, 1936, 217–222, 223–232; Cox et al., U. S. Pub. Health Service, Public Health Rept., *56*, 1941, 1905–1906; Davis, Am. Jour. Hyg., *32* (C), 1940, 45–59; Eklund and Blumstein, Jour. Am. Med. Assoc., *111*, 1938, 1734–1735; Feemster, Am. Jour. Public Health, *28*, 1938, 1403–1410; Finkelstein et al., Jour. Inf. Dis., *66*, 1940, 117–126; Fothergill and Dingle, Science, *88*, 1938, 549–550; Fothergill et al., New England Jour. Med., *219*, 1938, 411; Giltner and Shahan, Science, *78*, 1933, 63–64; Jour. Am. Vet. Med. Assoc., *88*, (N.S. *41*), 1936, 363–374; Graham and Levine, Am. Jour. Vet. Res., *2*, 1941, 430–435; Grundmann et al., Jour. Inf. Dis., *72*, 1943, 163–171; Havens et al., Jour. Exp. Med., *77*, 1943, 139–153; Higbie and Howitt, Jour. Bact., *29*, 1935, 399–406; Howitt, Jour. Inf. Dis., *55*, 1934, 138–149; *61*, 1937, 88–95; *67*, 1940, 177–187; Science, *88*, 1938, 455–456; Howitt and Van Herick, Jour. Inf. Dis., *71*, 1942, 179–191; Kelser, Jour. Am. Vet. Med. Assoc., *82*, 1933, 767–771; King, Jour. Exp. Med., *71*, 1940, 107–112; *76*, 1942, 325–334; Kitselman and Grundmann, Kansas Agr. Exp. Sta., Tech. Bull. 50, 1940, 1–15; Merrill and TenBroeck, Jour. Exp. Med., *62*, 1935, 687–695; Meyer et al., Science, *74*, 1931, 227–228; Mitchell et al., Canadian Jour. Comp. Med., *3*, 1939, 308–309; Morgan, Jour. Exp. Med., *74*, 1941, 115–132; Morgan et al., *ibid.*, *76*, 1942, 357–369; Olitsky et al., *ibid.*, *77*, 1943, 359–374; Remlinger and Bailly, Compt. rend. Soc. Biol., Paris, *121*, 1936, 146–149; *122*, 1936, 518–519; *123*, 1936, 562–563; Sabin and Olitsky, Proc. Soc. Exp. Biol. and Med., *38*, 1938, 597–599; Sellards et al., Am. Jour. Hyg., *33* (B), 1941, 63–68; Shahan and Eichhorn, Am. Jour. Vet. Res., *2*, 1941, 218–220; Sharp et al., Proc. Soc. Exp. Biol. and Med., *51*, 1942, 206–207; Arch. Path., *36*, 1943, 167–176; Syverton and Berry, *ibid.*, *34*, 1936, 822–

824; Jour. Bact., *33*, 1937, 60; Am. Jour. Hyg., *32* (B), 1940, 19–23; *33* (B), 1941, 37-41; Jour. Exp. Med., *73*, 1941, 507–529; Taylor et al., Jour. Inf. Dis., *67*, 1940, 59–66; *69*, 1941, 224–231; *72*, 1943, 31–41; TenBroeck, Arch. Path., *25*, 1938, 759 (Abst.); TenBroeck and Merrill, Proc. Soc. Exp. Biol. and Med., *31*, 1933, 217–220; TenBroeck et al., Jour. Exp. Med., *62*, 1935, 677-685; Traub and Ten Broeck, Science, *81*, 1935, 572; Tyzzer and Sellards, Am. Jour. Hyg., *33* (B), 1941, 69–81; Tyzzer et al., Science, *88*, 1938, 505–506; van Roekel and Clarke, Jour. Am. Vet. Med. Assoc., *94* (N.S. *47*), 1939, 466–468; Webster and Wright, Science, *88*, 1938, 305–306; Wesselhoeft et al., Jour. Am. Med. Assoc., *111*, 1938, 1735–1740; Wright, Am. Jour. Hyg., *36*, 1942, 57-67.

8. **Erro bornensis** *spec. nov.* From Borna, name of a town in Saxony where a severe epizootic occurred in 1894 to 1896.

Common name: Borna-disease virus.

Hosts: Horse, cow, sheep, perhaps deer. Experimentally, also rabbit, guinea pig, rat (more susceptible when old than when younger), mouse; *Macaca mulatta* (Zimmermann) rhesus monkey.

Insusceptible species: Ferret, cat, pigeon; probably dog.

Geographical distribution: Würtemburg, Germany, North and South America, Hungary, Russia, Belgium, France, Italy, Roumania.

Induced disease: In horse, encephalomyelitis characterized by lassitude, indifference to external stimuli; later intermittent excitement, difficulty in mastication and deglutition, spasms in various muscles, champing, excessive salivation; pupils unequal in size; paralysis of hindquarters, tail, muscles of tongue, or muscles of back; temperature usually normal; death in 20 to 37 hours or, less often, recovery after about 1 to 3 weeks. Virus may pass placenta and infect fetus in pregnant animals.

Transmission: To rabbit, experimentally by feeding and by injection intracerebrally, intraocularly, nasally, intravenously, subcutaneously, or intraperitoneally; not by living in same cage.

Immunological relationships: No cross immunity conferred by the Western strain of equine encephalomyelitis virus. Isolate of Borna disease virus from the horse immunizes rabbits against isolate from sheep, and *vice versa*. Herpes and rabies viruses do not immunize rabbits against subsequent infection by Borna disease virus.

Thermal inactivation: At 50 to 57° C in 30 minutes; at 70° C in 10 minutes.

Filterability: Passes Berkefeld N and Mandler filters, but with difficulty. Passes collodion membranes of average pore diameter 400 millimicrons readily, 200 millimicrons with difficulty, 175 millimicrons not detectibly. May be separated by differential filtration from louping-ill virus, which will pass even a 125-millimicron membrane.

Other properties: Particle size estimated from filtration data as 85 to 125 millimicrons. Optimum pH for stability in broth at 15 to 20° C is 7.4 to 7.6; very sensitive to greater alkalinity Viable after 327 days dry at laboratory temperatures. Viable at least 6 months in 50 per cent glycerine. Inactivated by putrefaction in 5 days; by 1 per cent carbolic acid in 4, not in 2, weeks.

Literature: Barnard, Brit. Jour. Exp. Path., *14*, 1933, 205–206; Covell, Proc. Soc. Exp. Biol. and Med., *32*, 1934, 51–53; Elford and Galloway, Brit. Jour. Exp. Path., *14*, 1933, 196–205; Howitt and Meyer, Jour. Infect. Dis., *54*, 1934, 364–367; Nicolau and Galloway, Brit. Jour. Exp. Path., *8*, 1927, 336–341, and in Medical Research Council, Special Report Series No. 121, London, 1928, 90 pp., Ann. Inst. Pasteur, *44*, 1930, 673–696; *45*, 1930, 457–523; Zwick et al., Ztschr. Infektionskr. parasit. Krankh. u. Hyg. d. Haustiere, *30*, 1926, 42–136; *32*, 1927, 150–179.

Genus II. **Legio** *gen. nov.*

Viruses of the Poliomyelitis Group, often recoverable from feces of infected hosts, probably because of involvement of some part of the alimentary tract; usually there is also obvious involvement of some part of the nervous system. Generic name from Latin *legio*, an army or legion.

The type species is *Legio debilitans spec. nov.*

Key to the species of genus **Legio.**

I. Affecting man (see also IV below).
  1. *Legio debilitans.*
  2. *Legio crebea.*
  3. *Legio simulans.*

II. Latent in, or affecting, mouse.
  4. *Legio muris.*

III. Affecting birds.
  5. *Legio gallinae.*

IV. Affecting swine and swineherds.
  6. *Legio suariorum.*

1. **Legio debilitans** *spec. nov.* From Latin *debilitare*, to weaken or maim.

Common names: Poliomyelitis virus, virus of infantile paralysis.

Hosts: *HOMINIDAE—Homo sapiens* L., man. Experimentally, *Cercopithecus aethiops sabaeus*, green African monkey; *Macaca mordax*; *M. mulatta*, the rhesus monkey; *M. irus*, the cynomolgus monkey; mona monkey; for some isolates, *Sigmodon hispidus* Say and Ord, cotton rat; mouse; guinea pig; white rat.

Insusceptible species: Sheep ("refractory" but forms neutralizing antibodies), chicken.

Geographical distribution: Almost world-wide.

Induced disease: In man, probably subclinical in most cases, in view of the presence of specific antibodies in sera from the great majority of adults in all parts of the world; virus probably infects some part of the alimentary tract, being found in stools of most clinical cases, of most apparently healthy contacts, and even of some individuals who have recovered from abortive attacks (in one case 123 days after attack); clinical disease, largely in children, is characterized by invasion of central nervous system, with effects ranging from sore throat, fever, vomiting, and headache to sudden and severe paralysis; the muscles most often involved are those of the legs, but there may be paralysis of abdominal or intercostal muscles. Virus not in urine or saliva, rarely in nasal washings; more often in stools of young than of old patients; in walls of pharynx, ileum, descending colon. Virus has been recovered from sewage. Incidence and fatality affected by racial characteristics, the first lower and the second higher in negroes than in whites in the United States. In monkey, similar disease, no virus in blood, relapse with reappearance of virus reported; in isolated intestinal loops, infection does not occur through normal mucosa in absence of intestinal contents; disease more severe in summer than in autumn, in autumn than in winter; more severe in older than in younger monkeys; no immunity follows inoculation unless obvious disease occurs.

Transmission: Transmission in milk has been suspected and at times confirmed. Virus has been recovered from mixed samples of flies in an epidemic area. No definite arthropod vector has been incriminated. Experimentally, in *Cercopithecus aethiops sabaeus*, the green

African monkey, by intracerebral, intranasal, and intraabdominal inoculation.

Serological relationships: Specific neutralizing antibodies arise after experimental infection in monkeys, but reinfection is not prevented; only a minority of human convalescent sera neutralize virus *in vitro*, the most potent sera probably being obtained from those with transient or light paralysis. Cross neutralization between monkey-passage and murine (cotton-rat and mouse) strains. No cross-neutralization reaction with lymphocytic choriomeningitis virus. Isolates differ somewhat antigenically, homologous titers being higher than heterologous titers in some neutralization tests.

Thermal inactivation: At or below 75° C in 30 minutes.

Filterability: Passes membrane about 35, not 30, millimicrons in average pore diameter.

Other properties: Infectivity of virus maintained well at −76° C or in glycerine but poorly when dried or just frozen. Inactivated readily by hydrogen peroxide. Particle diameter estimated as about 12 millimicrons by filtration studies. Precipitated by half-saturated ammonium sulphate solutions. Electron micrographs show elliptical particles 20 to 30 millimicrons in diameter; impure infectious materials show long threads 20 by 75 to 500 millimicrons in size. Component probably virus has sedimentation constant $S_{20°} = 62 \times 10^{-13}$ cm per sec. per dyne. Inactivated by potassium hydroxide, copper sulfate and potassium permanganate. Stable from pH 2.2 to 10.4 for 2 hours at 37° C.

Literature: Armstrong and Harrison, U. S. Pub. Health Service, Public Health Rept., *50*, 1935, 725–730; Aycock, Am. Jour. Hyg., *7*, 1927, 791–803; Burnet and Jackson, Austral. Jour. Exp. Biol. and Med. Sci., *17*, 1939, 261–270; *18*, 1940, 361–366; Burnet et al., *ibid.*, *17*, 1939, 253–260, 375–391; Elford et al., Jour. Path. and Bact., *40*, 1935, 135–141; Flexner, Jour. Exp. Med., *62*, 1935, 787–804; *63*, 1936, 209–226; *65*, 1937, 497–513; Gard, *ibid.*, *71*, 1940, 779–785; Gordon and Lennette, Jour. Inf. Dis., *64*, 1939, 97–104; Harmon, *ibid.*, *58*, 1936, 331–336; Heaslip, Austral. Jour. Exp. Biol. and Med. Sci., *16*, 1938, 285–286; Howitt, Jour. Inf. Dis., *51*, 1932, 565–573; *53*, 1933, 145–156; Hudson and Lennette, Am. Jour. Hyg., *17*, 1933, 581–586; Jungeblut and Bourdillon, Jour. Am. Med. Assoc., *123*, 1943, 399–402; Jungeblut and Sanders, Jour. Exp. Med., *72*, 1940, 407–436; *76*, 1942, 127–142; Jungeblut et al., *ibid.*, *75*, 1942, 611–629; *76*, 1942, 31–51; Kessel et al., Am. Jour. Hyg., *27*, 1938, 519–529; Jour. Exp. Med., *74*, 1941, 601–609; Kolmer et al., Jour. Inf. Dis., *61*, 1937, 63–68; Kramer et al., Jour. Exp. Med., *69*, 1939, 46–67; Lennette and Hudson, Jour. Inf. Dis., *58*, 1936, 10–14; Loring and Schwerdt, Jour. Exp. Med., *75*, 1942, 395–406; McClure and Langmuir, Am. Jour. Hyg., *35*, 1942, 285–291; Melnick, Jour. Exp. Med., *77*, 1943, 195–204; Moore and Kessel, Am. Jour. Hyg., *38*, 1943, 323–344; Moore et al., *ibid.*, *36*, 1942, 247–254; Morales, Jour. Inf. Dis., *46*, 1930, 31–35; Olitsky and Cox, Jour. Exp. Med., *63*, 1936, 109–125; Paul et al., Am. Jour. Hyg., *17*, 1933, 587–600; 601–612; Jour. Exp. Med., *71*, 1940, 765–777; Sabin, *ibid.*, *69*, 1939, 507–516; Sabin and Olitsky, *ibid.*, *68*, 1938, 39–61; Sabin and Ward, *ibid.*, *73*, 1941, 771–793; *74*, 1942, 519–529; *75*, 1942, 107–117; Sabin et al., Jour. Bact., *31*, 1936, 35–36 (Abst.); Sanders and Jungeblut, Jour. Exp. Med., *75*, 1942, 631–649; Schultz and Gebhardt, Jour. Inf. Dis., *70*, 1942, 7–50; Schultz and Robinson, *ibid.*, *70*, 1942, 193–200; Stimpert and Kessel, Am. Jour. Hyg., *29*, (B), 1939, 57–66; Theiler, Medicine, *20*, 1941, 443–462; Theiler and Bauer, Jour. Exp. Med., *60*, 1934, 767–772; Trask and Paul, *ibid.*, *58*, 1933, 531–544; *73*, 1941, 453–459; Trask et al., *ibid.*, *77*, 1943, 531–544; Turner and Young, Am. Jour. Hyg., *37*, 1943, 67–79; Wolf, Jour. Exp. Med., *76*, 1942, 53–72; Young and Merrell, Am. Jour. Hyg., *37*, 1943, 80–92.

2. Legio erebea *spec. nov.* From Latin *erebeus*, belonging to the Lower World.

Common names: Choriomeningitis virus, lymphocytic choriomeningitis virus.

Hosts: *MURIDAE—Mus musculus* L., gray or white mouse. *HOMINIDAE—Homo sapiens* L., man. *CERCOPITHECIDAE—Macaca mulatta*, rhesus monkey. Experimentally, also guinea pig; white rat; dog (masked); ferret (masked); *Macaca irus*, crab-eating macaque; Syrian hamster; chick- or mouse-embryo serum-Tyrode solution culture; chick embryo.

Insusceptible species: Pig, rabbit, field vole, bank vole, canary, hen, parakeet.

Geographical distribution: France, England, United States.

Induced disease: In white mouse, more virulent in young than in old individuals; infection may take place *in utero* or soon after birth; some mice become carriers after recovery, with virus in organs, blood, urine, and nasal secretions; carriers are immune to large intracerebral inoculations of virus; experimentally, 5 to 12 days after intracerebral inoculation of susceptible mice, somnolence, photophobia, tremors of the legs, tonic spasms of muscles in the hindquarters upon stimulation; recovery or death. In man, disease may be subclinical at times as shown by the fact that some supposedly normal sera contain specific antibodies; not all clinical cases develop protecting antibodies against testing strains, so that disease may be somewhat commoner than can be ascertained readily; in all cases benign, but in the more severe of these an acute aseptic meningitis; after incubation period of 1½ to 3 days, spells of fever extending as long as 3 weeks; late in the disease there may be a meningeal reaction both clinically and cytologically; lymphocytes and some large mononuclear cells appear in the meningeal fluids, although symptoms remain benign; there may be virus in the blood from the beginning of fever to the end of the second week; the spinal fluid is not infective at first but may become so before there is a change in cell count; urine and saliva remain uninfectious.

Transmission: In white mouse, by contact with mice infected when young, not with those infected when old; nasal mucosa considered portal of entry. In wild gray mouse of the same species, *Mus musculus*, by contact but less readily than in white mouse. Experimentally, by mosquito, *Aëdes aegypti* L. (*CULICIDAE*), at 26 to 34° C; by bedbug, *Cimex lectularius* (*CIMIDAE*), but defecation on site of bitten area is essential, bite alone being ineffective. Experimentally, to guinea pig, by application of virus to normal and apparently intact skin; not by contamination of food or litter.

Serological relationships: Serum of recovered subjects usually neutralizes choriomeningitis virus. Hyperimmune serum is ineffective against pseudo-lymphocytic choriomeningitis virus and hyperimmune serum for that virus is ineffective in its turn when used with choriomeningitis virus. No cross neutralization with St. Louis encephalitis virus. A specific soluble antigen associated quantitatively with virus in all hosts fixes complement in the presence of immune serum; virus does so poorly if at all; the anti-soluble-substance antibodies seem to be independent of virus-neutralizing antibodies. A soluble protein, readily separable from virus, gives a specific precipitin reaction with immune serum; antibodies concerned are probably not the virus-neutralizing antibodies.

Immunological relationships: Intraperitoneal injection of about 160 intracerebral lethal doses has been found to protect the white mouse against infection by subsequent intracerebral injection of 10,000 lethal doses. The immune mouse differs from the immune guinea pig in showing no neutralizing antibodies in its blood; even the guinea pig may develop resistance before antibodies appear in its serum. Formalized vaccines made from

guinea pig tissues immunize the guinea pig but vaccines made from mouse tissues do not. Mice immune to this virus are susceptible to infection with pseudo-lymphocytic choriomeningitis virus and *vice versa*.

Thermal inactivation: At 55 to 56° C in 20 minutes.

Filterability: Passes Berkefeld V, N, and W filters and, with difficulty, a Seitz asbestos pad.

Other properties: Infective at least 206 days in storage at 4 to 10° C in 50 per cent neutral glycerine in 0.85 per cent saline. Infective particle calculated to be 37 to 55 millimicrons in diameter on the basis of centrifugation studies; 40 to 60 millimicrons by ultrafiltration tests. Inactivated by soap with loss of mouse-immunizing capacity.

Literature: Armstrong and Dickens, U. S. Pub. Health Service, Public Health Rept., *50*, 1935, 831–842; Armstrong and Lillie, *ibid.*, *49*, 1934, 1019–1027; Armstrong and Wooley, *ibid.*, *50*, 1935, 537–541; Jour. Am. Med. Assoc., *109*, 1937, 410–412; Baird and Rivers, Am. Jour. Pub. Health, *28*, 1938, 47–53; Casals-Ariet and Webster, Jour. Exp. Med., *71*, 1940, 147–154; Dalldorf, *ibid.*, *70*, 1939, 19–27; Dalldorf and Douglass, Proc. Soc. Exp. Biol. and Med., *39*, 1938, 294–297; Findlay and Stern, Jour. Path. and Bact., *43*, 1936, 327–338; Findlay et al., Lancet, *230*, 1936 (*1*), 650–654; Howard, Jour. Inf. Dis., *64*, 1939, 66–77; Laigret and Durand, Compt. rend. Acad. Sci., *203*, 1936, 282–284; Lépine and Sautter, Ann. Inst. Pasteur, *61*, 1938, 519–526; Lépine et al., *ibid.*, *204*, 1937, 1846–1848; MacCallum and Findlay, Brit. Jour. Exp. Path., *21*, 1940, 110–116; Milzer, Jour. Inf. Dis., *70*, 1942, 152–172; Rivers and Scott, Jour. Exp. Med., *63*, 1936, 415–432; Scott and Elford, Brit. Jour. Exp. Path., *20*, 1939, 182–188; Scott and Rivers, Jour. Exp. Med., *63*, 1936, 397–414; Shaugnessy and Zichis, *ibid.*, *72*, 1940, 331–343; Smadel and Wall, *ibid.*, *72*, 1940, 389–405; *75*, 1942, 581–591; Smadel et al., Proc. Soc. Exp. Biol. and Med., *40*, 1939, 71–73; Jour. Exp. Med., *70*, 1939, 53–66; *71*, 1940, 43–53; Stock and Francis, *ibid.*, *77*, 1943, 323–336; Traub, Science, *81*, 1935, 298–299; Jour. Exp. Med., *63*, 1936, 533–546, 847–861; *64*, 1936, 183–200; *66*, 1937, 317–324; *68*, 1938, 95–110, 229–250; *69*, 1939, 801–817.

3. **Legio simulans** *spec. nov.* From Latin *simulare*, to imitate, in reference to resemblance of this virus to the preceding in many respects, though not in size or antigenic properties.

Common name: Pseudo-lymphocytic choriomeningitis virus.

Hosts: *HOMINIDAE—Homo sapiens* L., man. Experimentally, also mouse, guinea pig, rhesus monkey; chorioallantoic membrane of chick embryo.

Induced disease: In man, benign aseptic lymphocytic meningitis with virus in cerebro-spinal fluid; severe frontal headache, drowsiness, irritability, vomiting, eventual complete recovery. In mouse, experimentally, roughened fur, spontaneous tremor, hunched attitude, irritability, clonic movements ending with tonic convulsions on stimulation, temporary recovery from spasm with survival a few hours or instant death.

Serological relationships: Hyperimmune sera for lymphocytic choriomeningitis virus are ineffective for this virus, and *vice versa*. In man, after recovery, neutralizing antibody is strong at 1 month, fading before 7 months.

Immunological relationships: Mice acquire specific resistance to reinfection after experimental disease; mice immune to lymphocytic choriomeningitis virus are susceptible to pseudo-lymphocytic choriomeningitis virus and *vice versa*.

Thermal inactivation: At 56° C, not at 45° C, in 30 minutes.

Filterability: Passes Berkefeld V, not N, filter candle; Gradacol membrane of 320, not 300, millimicron average pore diameter.

Other properties: Particle diameter calculated to be not above 150 to 225 millimicrons, from filtration experiments.

Viable at least 1 month at 4° C, at least 1 year in 50 per cent glycerine, 40 days in 0.25 per cent phenol, 1 year when dried from frozen material. Inactivated by 0.05 per cent formalin at 4° C in 48 hours; by boiling in 5 minutes.

Literature: MacCallum et al., Brit. Jour. Exp. Path., *20*, 1939, 260–269.

4. **Legio muris** *spec. nov.* From Latin *mus*, mouse.

Common names: Mouse-poliomyelitis virus, Theiler's-disease virus.

Host: *MURIDAE—Mus musculus* L., white mouse.

Insusceptible species: *CERCOPITHECIDAE—Macaca mulatta* (Zimmermann), rhesus monkey.

Geographical distribution: United States, Japan, Germany, Palestine; probably widespread wherever white mice are raised.

Induced disease: In white mouse, ordinarily no obvious disease, virus occurring in feces and not being recoverable from thoracic or abdominal viscera or head (probable source is in abdominal wall; virus has been recovered most abundantly from intestinal contents, in moderate amounts from walls of intestine and in smaller concentration from mesenteric lymph glands); occasionally, individual mice show flaccid paralysis of hind legs, and brain or spinal-cord suspensions from these contain the virus; mice inoculated intracerebrally show flaccid paralysis in 7 to more than 30 days, first in one limb, later usually in all; the tail does not become paralyzed; very young inoculated mice may die without first showing paralysis; very old inoculated mice may become infected without showing obvious disease; some affected mice recover and those showing residual paralysis may become carriers of virus. In affected, experimentally inoculated mice, acute necrosis of ganglion cells of anterior horn of spinal cord; necrosis also of isolated ganglion cells of cerebrum. Later, marked neuronophagia. Perivascular infiltration in brain and spinal cord. The reciprocal of the incubation period has been found approximately proportional to the logarithm of the amount of virus inoculated, thus serving to measure the concentration of samples of virus. Old mice less susceptible than young.

Transmission: Experimentally, by intracerebral, intranasal and intraperitoneal inoculation. Has been found to persist in adult flies, *Musca domestica* L. (*MUSCIDAE*) and other species, as long as 12 days after experimental feeding whereas mouse-adapted human poliomyelitis virus persists only 2 days in *Musca domestica* and not at all in some other species.

Serological relationships: Sera containing antibodies to the Lansing strain of human poliomyelitis virus fail to protect against mouse poliomyelitis virus.

Immunological relationships: Recovered mice are immune to various heterologous isolates or strains. No evidence of immunological relationship with virus of human poliomyelitis has been obtained, save that mice paralyzed with mouse poliomyelitis virus show some resistance to infection with the Lansing strain of human poliomyelitis virus; this has been interpreted as possibly no more than an interference phenomenon, since it seems to depend on actual paralysis.

Filterability: Passes Berkefeld N and other Berkefeld filters and Chamberland L_3 filter.

Other properties: Viable at least 14 months at −78° C; at least 150 days in 50 per cent glycerine at 2 to 4° C. Most stable near pH 8.0 and pH 3.3. Inactivated readily at 37° C by 1 per cent hydrogen peroxide. Particle diameter estimated as 9 to 13 millimicrons from filtration studies. Sedimentation constant, $S_{20°} = 160$ to 170×10^{-13} cm per sec. per dyne.

Literature: Bang and Glaser, Am. Jour. Hyg., *37*, 1943, 320-324; Gahagan and Stevenson, Jour. Inf. Dis., *69*, 1941, 232–237; Gard, Jour. Exp. Med., *72*, 1940, 69–77; Gard and Pedersen, Science, *94*, 1941, 493–494; Gildemeister and Ahlfeld,

Cent. f. Bakt., I Abt., Orig., *142*, 1938, 144–148; Iguchi, Kitasato Arch. Exp. Med., *16*, 1939, 56–78; Olitsky, Jour. Exp. Med., *72*, 1940, 113–127; Theiler, Science, *80*, 1934, 122; Jour. Exp. Med., *65*, 1937, 705–719; Theiler and Gard, *ibid.*, *72*, 1940, 49–67, 79–90; Young and Cumberland, Am. Jour. Hyg., *37*, 1943, 216–224.

5. **Legio gallinae** *spec. nov.* From Latin *gallina*, hen.

Common names: Avian encephalomyelitis virus, infectious avian encephalomyelitis virus.

Host: *PHASIANIDAE—Gallus gallus* (L.), chicken (embryo not susceptible; in culture media, minced whole embryo in serum-Tyrode solution suffices to maintain virus, but embryo brain alone does not).

Insusceptible species: All tested species other than birds.

Geographical distribution: United States.

Induced disease: In chicken, fine or coarse tremors of whole body or only of head and neck or of legs; progressive ataxia; eyes dull, some loss of weight, weakness of legs, and progressive incoordination of leg muscles; somnolence precedes death; about 75 per cent die within 5 days of onset, 90 per cent within a week, the remainder showing a staggering, ataxic gait for weeks, some continuously tremulous; recovered birds, however, may produce eggs well; microscopic focal collections of glia cells, perivascular infiltration, degeneration of Purkinje's cells and degeneration of nerve cells; foci of infiltration throughout brain and spinal cord; virus not detected in the blood of affected chickens.

Transmission: Not through egg. Experimentally, by intracerebral injection.

Serological relationships: Specific antiserum neutralizes homologous virus but not the Eastern strain of equine encephalitis virus; antiserum specific for the latter does not neutralize avian encephalomyelitis virus.

Filterability: Passes Berkefeld V and N as well as Seitz 1 and 2 filters; also membranes 73 millimicrons in average pore diameter.

Other properties: Survives in 50 per cent glycerine for at least 88 days and frozen for at least 68 days. Infective particle estimated to be 20 to 30 millimicrons in diameter, by filtration studies.

Literature: Jones, Science, *76*, 1932, 331–332; Jour. Exp. Med., *59*, 1934, 781–798; Kligler and Olitsky, Proc. Soc. Exp. Biol. and Med., *43*, 1940, 680–683; Olitsky, Jour. Exp. Med., *70*, 1939, 565–582; Olitsky and Bauer, Proc. Soc. Exp. Biol. and Med., *42*, 1939, 634–636; Van Roekel et al., Jour. Am. Vet. Med. Assoc., *93* (N.S. *46*), 1938, 372–375.

6. **Legio suariorum** *spec. nov.* From Latin *suarius*, swineherd.

Common name: Swineherds'-disease virus.

Hosts: *SUIDAE—Sus scrofa* L., swine. *HOMINIDAE—Homo sapiens* L., man. Experimentally, with fever as only symptom, white rat, cat, ferret, mouse; perhaps *Macaca mulatta* (Zimmermann), rhesus monkey.

Geographical distribution: Europe.

Induced disease: In man, a benign meningitis without sequelae, somewhat similar to lymphocytic choriomeningitis in man; cell counts in spinal fluids may be as high as 1200 to 1400; 4 to 7 (average 8) days after infection, fever lasting 3 to 21 days (average 9); sometimes conjunctivitis, more often a reddish maculopapillose eruption; severe sweating frequent; hemorrhagic tendency; blood in feces; recovery. Blood, urine, feces infectious, not spinal fluid or mucous excretions. Especially affecting young men, not often old men or women, among those having contact with swine or swine-producing quarters.

Transmission: Excreta of pigs, even as used for manure, are infective. Experimentally, to man, by subdermal or intramuscular injection.

Serological relationships: Serum from recovered cases neutralizes the virus.

Immunological relationships: Specific immunity follows attack of the disease.

Filterability: Passes Chamberland L_2 filter.

Literature: Durand et al., Compt. rend. Acad. Sci., Paris, *203*, 1936, 830–832, 957–959, 1032–1034; Arch. Inst. Pasteur de Tunis, *26*, 1937, 213–227; 228–249; *27*, 1938, 7–17.

Genus III. **Formido** *gen. nov.*

Viruses of the Rabies Group, inducing diseases characterized by involvement of the nervous system only. Generic name from Latin *formido*, a frightful thing.

The type and only recognized species is *Formido inexorabilis spec. nov.*

1. **Formido inexorabilis** *spec. nov.* From Latin *inexorabilis*, implacable.

Common name: Rabies virus.

Hosts: *CANIDAE—Canis familiaris* L., dog. *FELIDAE—Felis catus* L., domestic cat; *F. negripes*, black-footed cat; *F. ocreata*, wild cat. *HOMINIDAE—Homo sapiens* L., man. *MUSTELIDAE—Ictonyx orangiae*, polecat. *SCIURIDAE—Geosciurus capensis*, ground squirrel. *VIVERRIDAE—Cynictis penicillata*, yellow mongoose (yellow meercat); *Genetta felina* (Thunb.), genet cat; *Myonax pulverulentus*, small, grey mongoose; *Suricata suricatta*, Cape suricate or common meercat. Cattle, sheep, pig, horse, wolf. *Cynalopex chama*, silver jackal. *Phyllostoma superciliatum*, vampire bat; *Desmodus rufus*, vampire bat; *Artibeus planirostris trinitatis*, fruit-eating bat. Experimentally, also *Mus musculus* L., white mouse; *Peromyscus polionotus polionotus* (Wagner), white-footed mouse; tissue cultures of 5 or 6-day-old rat- or mouse-embryo brain; chick embryo (allantois not regularly infected, but virus regularly reaches brain of embryo without injuring it; chick may hatch with titer of 1:100 or 1:1000 in brain). Chicken; mouse hawk (*Buteo vulgaris*); pigeon, owl, goose; stork (*Ciconia ciconia*); pheasant (*Diardigallus diardi* B.P.).

Insusceptible species: Reptiles, fish. No mammal is known to be insusceptible.

Geographical distribution: Almost world-wide; absent only from relatively isolated countries or communities.

Induced disease: In dog, after a short incubation period (generally less than 10 days) altered behavior, hiding, lack of obedience, perverted appetite leading to ingestion of straw, paper, earth, and other unaccustomed materials; excitement, unprovoked biting (which may transmit the virus to new hosts), aimless wandering, excess salivation, progressive inability to swallow, alteration of bark to characteristic high pitched tone; staggering, paresis of hindquarters tending toward paralysis and involvement of anterior parts of the body; paralysis of lower jaw, muscular spasms, marked emaciation, death except perhaps in rare instances. In man, after a relatively long incubation period depending on site of implantation (perhaps 27 to 64 days), a uniformly fatal disease, characterized by altered behavior, increased excitability, thirst, pharyngeal spasm with progressive inability to swallow, labored and noisy respiration, death in 3 or 4 days after onset, with or without paroxysm. In sheep, increased sexual desire; tendency to pull wool from other sheep or themselves; light butting, increasing until some ewes, after violent exercise, appear to faint; prostration within 1 to 4 days; death within 2 days from onset of locomotory paralysis. In mouse, experimentally, by intracerebral inoculation, apathy, sluggishness, roughening of hair, tremor, convulsions, prostration, death; sometimes flaccid paralysis of hind legs before death.

Transmission: Usually by bite of dog or some closely related animal; occasionally by bites of cats; rarely by bites

of rabid horses or cattle. Not by contamination of food. In Brazil and Trinidad, probably by the vampire bat, which has been found infected in nature.

Serological relationships: Specific flocculation of rabies virus occurs in the presence of immune serum from rabbit or guinea pig; strains differ in relative amounts of antigenic constituents, as shown by absorption tests. Complement fixation occurs in the presence of virus and guinea-pig antiserum. Neutralizing antibodies are specific.

Immunological relationships: Virus exposed to ultraviolet light tends to lose its virulence before its immunizing potency. Passive immunization succeeds in white mice if antiserum is injected intracerebrally ½ hour before, but not 24 hours before or 2 hours after, virus. Chloroform-treated vaccines more effective than phenolized vaccines, but irritative.

Thermal inactivation: At 60 to 70° C in 15 minutes; in brain tissues, at 45° C in 24 hours.

Filterability: Passes Berkefeld V filter.

Other properties: Viable at least 2 months at 5° C in liquid or dry state. Infective particle between 100 and 240 millimicrons in diameter, by filtration studies.

Literature: Bernkopf and Kligler, Brit. Jour. Exp. Path., *18*, 1937, 481–485; Casals, Jour. Exp. Med., *72*, 1940, 445–451, 453–461; Covell and Danks, Am. Jour. Path., *8*, 1932, 557–572; Dawson, Science, *89*, 1939, 300–301; Am. Jour. Path., *17*, 1941, 177–188; Galloway, Brit. Jour. Exp. Path., *15*, 1934, 97–105; Goodpasture, Am. Jour. Hyg., *1*, 1925, 547–582; Haupt and Rehaag, Ztschr. f. Infektionskrankh., *22*, 1921, 76–88, 104–127; Havens and Mayfield, Jour. Inf. Dis., *50*, 1932, 367–376; *51*, 1932, 511–518; *52*, 1933, 364–373; Henderson, Vet. Med., *37*, 1942, 88–89; Hodes et al., Jour. Exp. Med., *72*, 1940, 437–444; Hoyt et al., Jour. Inf. Dis., *59*, 1936, 152–158; Hurst and Pawan, Lancet, *221*, 1931 (*2*), 622–628; Jour. Path. and Bact., *35*, 1932, 301–321; Johnson and Leach, Am. Jour. Hyg., *32* (B), 1940, 38–45; Kligler and Bernkopf, Proc. Soc. Exp. Biol. and Med., *39*, 1938, 212–214; Am. Jour. Hyg., *33* (B), 1941, 1–8; Leach and Johnson, *ibid.*, *32* (B), 1940, 74–79; Metivier, Jour. Comp. Path. and Therap., *48*, 1935, 245–260; Peragallo, Giorn. di batteriol. e immunol., *18*, 1937, 289–290; Snyman, Onderstepoort Jour. Vet. Sci. and Anim. Indust., *15*, 1940, 9–140; Webster, Am. Jour. Pub. Health, *26*, 1936, 1207–1210; Jour. Exp. Med., *70*, 1939, 87–106; Am. Jour. Hyg., *30* (B), 1939, 113–134; Webster and Casals, Jour. Exp. Med., *71*, 1940, 719–730; *73*, 1941, 601–615; *76*, 1942, 185–194; Webster and Clow, *ibid.*, *66*, 1937, 125–131; Wyckoff, Am. Jour. Vet. Res., *2*, 1941, 84–90.

NOTE: The Negri body, a characteristic cell-inclusion in rabies, has been given the following names under the supposition that it represents stages in the life cycle of a protozoan parasite responsible for the disease: *Neuroryctes hydrophobiae* by Calkins, Jour. Cutaneous Diseases including Syphilis, *25*, 1907, 510; *Encephalitozoon rabiei* by Manouelian and Viala, Ann. Inst. Pasteur, *38*, 1924, 258; and *Glugea lyssae* by Levaditi, Nicolau and Schoen, Ann. Inst. Pasteur, *40*, 1926, 1048.

FAMILY IV. CHARONACEAE *FAM. NOV.*

Viruses of the Yellow-Fever Group, inducing diseases mainly characterized by fever and necrosis of tissues in the absence of obvious macule, papule, or vesicle formation or of conspicuous involvement of nerve cells.

Key to the genera of family **Charonaceae.**

I. Viruses of the Typical Yellow-Fever Group.
 Genus I. *Charon*, p. 1265.
II. Viruses of the Influenza Group.
 Genus II. *Tarpeia*, p. 1268.
III. Viruses of the Hog-Cholera Group.
 Genus III. *Tortor*, p. 1275.

Genus I. **Charon** *gen. nov.*

Viruses of the Typical Yellow-Fever Group, inducing diseases mainly characterized by acute non-contagious fever. Vectors dipterous insects, so far as known. Generic name from Latin *Charon*, ferryman of the Lower World.

The type species is *Charon evagatus spec. nov.*

Key to the species of genus **Charon.**

I. Vectors mosquitoes.
 1. *Charon evagatus.*
II. Vectors unknown, perhaps mosquitoes.
 2. *Charon vallis.*

1. **Charon evagatus** *spec. nov.* From Latin *evagor*, to spread abroad.

Common name: Yellow-fever virus.

Hosts: *HOMINIDAE—Homo sapiens* L., man. Experimentally, also *Cercopithecus tantalus* Ogilby; *C. aethiops*, African guenon (symptomless); *Cercocebus torquatus* (Kerr), collared mangabey; *Mus musculus* L., mouse; *Microtus agrestis*, field vole; *Sciurus vulgaris* L., red squirrel; *Macaca mulatta* (Zimmermann), rhesus monkey; *Macacus sinicus* Indian crown monkey; *M. cynomolgus*; *M. speciosus*; *Erinaceus europaeus*, hedge hog; *Gallus gallus* (L.), chicken (tolerant); *Dasyprocta aguti*, agouti (serial passage fails).

Insusceptible species: Cat, ferret, rabbit, rat; *Cricetus auratus*, golden hamster; *Apodemus sylvaticus*, wood vole; *Evotomys glareolus*, bank vole; pigeon, canary, pipistrelle bat; *Cricetomys gambianus*, pouched rat; dog, goat.

Geographical distribution: Tropical regions in general, especially Central and South America, West Indies, West Africa; anti-mosquito campaigns have tended to eradicate yellow-fever virus from parts of its former range.

Induced disease: In man, mild cases may occur, especially in natives where the disease is endemic, but in Europeans generally sudden fever without marked change in pulse rate after a 3 to 6-day incubation period; severe frontal headache, pains in the loin and legs and epigastric pain; gradual decrease in temperature to 98 or 99° F, weakening of pulse and slowing of heart beat in the absence of further temperature changes; jaundice, especially in sclerae, often in skin; albumen in urine, later bile-pigments also present; hemorrhages frequent especially in alimentary canal; fatty and necrotic changes in the liver; acute degeneration of renal parenchyma, splenic congestion; death may occur in the early acute state, but is more likely about the

fifth or sixth day; relapses may occur until 2 or 3 weeks after onset; case mortality varies from 10 to 90 per cent in different epidemics. A transitory immunity due to transfer of serum antibodies through the placenta protects offspring of immune mothers for a short time.

Transmission: By mosquitoes, *Aëdes aegypti* L., *Aëdes leucocelaemus* (D. and S.), *Haemogogus capricorni* Lutz (*CULICIDAE*). The mosquito *Aëdes aegypti* becomes infective, after feeding on a suitable virus source, in 4 days at 37° C, 5 days at 36° C, 6 days at 31° C, 8 days at 25.1° C, 9 to 11 days at 23.4° C, 18 days at 21° C, and 36, not 30, days at 18° C; virus in head, thorax, and abdomen before bites are infective; no evidence of transmission of virus through eggs to offspring or to larvae eating infected adults. Experimentally, also by *Aëdes scapularis* (Rondani), *A. fluviatilis* (Lutz), *A. luteocephalus*, *A. apico-annulatus* (*CULICIDAE*). Experimentally, by feeding, to *Macaca mulatta* and *Cercopithecus aethiops*; by rubbing infected blood into intact and unshaved skin of monkeys.

Serological relationships: Complement-fixation and precipitating antibodies are specific.

Immunological relationships: A specific immunity develops after an attack of the disease or after vaccination with virus grown in media containing tissues of chick embryo minus head and spinal cord.

Thermal inactivation: At 55 to 60° C, not at 50° C, in 10 minutes.

Filterability: Passes membranes of 55, and to some extent membranes of 50, millimicron average pore diameter. Passes Berkefeld V and N, as well as Chamberland F, filters.

Other properties: Particle estimated from filtration data to have a diameter of 17 to 28 millimicrons; by ultracentrifugation data, 19 millimicrons. Inactivated or inhibited by 30-minute exposure to 1:15 formalin, 1:6 ethyl alcohol; 1:300 yellowish eosin, 1:50 sodium oleate, 1:200 *liquor cresolis compositus*; viable after 30-minute exposure at 30° C to 1:7500 mercuric chloride, 1:150 phenol, 1:1500 hexylresorcinol, 1:150 sodium oleate. Sedimentation constant between 18 and 30×10^{-13} cm per sec. per dyne. Viable in 50 per cent glycerine at 2 to 4° C for 58, not for 100, days; in mouse brain at −8° C for 160 days. Viability may be lost on simple drying but retained if drying is carried on *in vacuo* over a desiccating agent.

Strains: Distinctive strains have been isolated. One, to which much study has been given, differs from the typical viscerotropic strain by possessing marked neurotropic or pantropic characteristics.

Literature: Bauer and Hughes, Am. Jour. Hyg., *21*, 1935, 101–110; Bauer and Mahaffy, *ibid.*, *12*, 1930, 155–174; 175–195; Bugher and Gast-Galvis, *ibid.*, *39*, 1944, 58–66; Bugher et al., *ibid.*, *39*, 1944, 16–51; Davis, *ibid.*, *16*, 1932, 163–176; Davis and Shannon, *ibid.*, *11*, 1930, 335–344; Davis et al., Jour. Exp. Med., *58*, 1933, 211–226; Findlay, Jour. Path. and Bact., *38*, 1934, 1–6; Lancet, *227*, 1934 (2), 983–985; Findlay and Clarke, Jour. Path. and Bact., *40*, 1935, 55–64; Findlay and MacCallum, Brit. Jour. Exp. Path., *19*, 1938, 384–388; Jour. Path. and Bact., *49*, 1939, 53–61; Findlay and Mackenzie, *ibid.*, *43*, 1936, 205–208; Findlay and Stern, *ibid.*, *40*, 1935, 311–318; Fox and Cabral, Am. Jour. Hyg., *37*, 1943, 93–120; Frobisher, Am. Jour. Hyg., *11*, 1930, 300–320; *13*, 1931, 585–613; *14*, 1931, 147–148; *18*, 1933, 354–374; Goodpasture, Am. Jour. Path., *8*, 1932, 137–150; Haagen, Deutsch. med. Wochnschr., *60*, 1934, 983–988; Hudson, Am. Jour. Path., *4*, 1928, 395–430; Klotz and Simpson, *ibid.*, *3*, 1927, 483–488; Laemmert and Moussatché, Jour. Inf. Dis., *72*, 1943, 228–231; Lloyd et al., Am. Jour. Hyg., *18*, 1933, 323–344; Trans. Roy. Soc. Trop. Med. and Hyg., *29*, 1936, 481–529; Mahaffy et al., Am. Jour. Hyg., *18*, 1933, 618–628; Pickels and Bauer, Jour. Exp. Med., *71*, 1940,

703–717; Ramsey, Am. Jour. Hyg., *13*, 1931, 129–163; Sawyer, *ibid.*, *25*, 1937, 221–231; Shannon et al., Science, *88* 1938, 110–111; Smith and Theiler, Jour. Exp. Med., *65*, 1937, 801–808; Smith et al., Am. Jour. Trop. Med., *18*, 1938, 437–468; Soper and De Andrade, Am. Jour. Hyg., *18*, 1933, 588–617; Soper et al., *ibid.*, *18*, 1933, 555–587; *19*, 1934, 549–566; *27*, 1938, 351–363; Stefanopoulo and Wassermann, Bull. Soc. Path. Exot., *26*, 1933, 557–559; Stokes et al., Am. Jour. Trop. Med., *8* 1928, 103–164; Theiler, Ann. Trop. Med. and Parasit., *24*, 1930, 249–272; Theiler and Smith, Jour. Exp. Med., *65*, 1937, 767–786, 787–800; Whitman, *ibid.*, *66*, 1937, 133–143.

2. **Charon vallis** *spec. nov.* From Latin *vallis*, valley.

Common name: Rift Valley fever virus.

Hosts: *HOMINIDAE—Homo sapiens* L., man. *BOVIDAE—Bos taurus* L., cow; *Ovis aries* L., sheep; *Capra hircus* L., goat. Experimentally, also *Sciurus carolinensis*, grey squirrel; ferret; *Cricetus auratus*, golden hamster; *Apodemus sylvaticus*, wood mouse; *Microtus agrestis* field vole; *Muscardinus avellanarius*, dormouse; rat; mouse; *Macaca mulatta*; *M. irus*; *Cebus fatuellus*; *C. chrysopus*; *Hapale jacchus*; *H. penicillata*; *Cercopithecus callitrichus* (symptomless); *Erythrocebus patas* (symptomless); *Cercocebus fuliginosus* (symptomless); chick embryo in Tyrode's solution; chorioallantoic membrane of chick embryo.

Insusceptible species: Horse, pig.

Geographical distribution: British East Africa.

Induced disease: In man, benign disease; after 5½ to 6 days, rigors, pains in back, fever for 12 to 36 hours, followed by recovery, with persistence of acquired immune bodies as long as 4 to 5 years after infection. In sheep (lambs), dullness, rapid respiration, collapse and death in a few hours or a chronic course; focal necrosis in liver. In chorioallantoic membrane of chick embryo, experimentally, areas of hyperplasia and of necrosis; connective tissue inflamed nearby; liver of embryo mottled with necrotic areas.

Transmission: Not by contacts. Mosquito, *Taeniorhynchus brevipalpis* (*CULICIDAE*), suspected as possible vector.

Serological relationships: Antisera for psittacosis, dengue fever, and sandfly fever viruses fail to protect against infection with Rift Valley fever virus. Specific neutralizing antibody in intraperitoneally neutral mixture with Rift Valley fever virus may be dissociated so as to free virus by direct dilution in saline solutions, by intranasal inoculation, or by employment of a small dose, all methods probably implying a dilution effect.

Immunological relationships: No cross immunity with yellow-fever or dengue-fever viruses. If Rift Valley fever virus is inoculated into *rhesus* monkey simultaneously with yellow-fever virus, the animal tends to be protected against death from yellow fever (interference effect), but one-day earlier inoculation of Rift Valley fever virus does not protect.

Thermal inactivation: At 56° C in 40, not 20, minutes.

Filterability: Passes Berkefeld V, N, and W filters; passes Chamberland L_2, L_3, L_5, L_7, L_{11} and occasionally L_{13} filters; passes membranes 150 millimicrons in average pore diameter freely, 90 millimicrons with difficulty, 70 millimicrons not at all.

Other properties: Viable at least 8 months at 4° C, more than 4 weeks dry in liver tissues, 6 months in ½ per cent carbolic acid at 4° C. Diameter of infective particle estimated from filtration studies to be between 23 and 35 millimicrons.

Strains: A neurotropic strain immunizes lambs without producing obvious illness, if given subcutaneously.

Literature: Broom and Findlay, Brit. Jour. Exp. Path., *14*, 1933, 179–181; Daubney et al., Jour. Path. and Bact., *34*, 1931, 545–579; Findlay, Trans. Roy.

Soc. Trop. Med. and Hyg., *25*, 1932, 229–266; *26*, 1932, 157–160; 161–168; Brit. Jour. Exp. Path., *17*, 1936, 89–104; Findlay and MacCallum, Jour. Path. and Bact., *44*, 1937, 405–424; Findlay and Mackenzie, Brit. Jour. Exp. Path., *17*, 1936, 441–447; Findlay et al., *ibid.*, *17*, 1936, 431–441; Francis and Magill, Jour. Exp. Med., *62*, 1935, 433–448; Horning and Findlay, Jour. Roy. Micr. Soc., *54*, 1934, 9–17; Mackenzie, Jour. Path. and Bact., *37*, 1933, 75–79; *40*, 1935, 65–73; Mackenzie et al., Brit. Jour. Exp. Path., *17*, 1936, 352–361; Saddington, Proc. Soc. Exp. Biol. and Med., *31*, 1934, 693–694; Schwentker and Rivers, Jour. Exp. Med., *59*, 1934, 305–313.

Genus II. **Tarpeia** *gen. nov.*

Viruses of the Influenza Group, inducing diseases characterized principally by involvement of the respiratory tract. Generic name from Latin *Tarpeia*, name of a Roman maiden who treacherously opened a citadel to an enemy.

The type species is *Tarpeia alpha spec. nov.*

Key to the species of genus **Tarpeia.**

I. Infecting man principally.
  1. *Tarpeia alpha.*
  2. *Tarpeia beta.*
  3. *Tarpeia premens.*

II. Affecting feline species.
  4. *Tarpeia felis.*

III. Affecting domestic cattle (calves).
  5. *Tarpeia vitulae.*

IV. Affecting canine species.
  6. *Tarpeia canis.*
  7. *Tarpeia vulpis.*

V. Affecting ferrets.
  8. *Tarpeia viverrae.*

VI. Affecting domestic fowl.
  9. *Tarpeia avium.*

1. **Tarpeia alpha** *spec. nov.* From first letter of Greek alphabet.

Common name: Influenza A virus; swine filtrate-disease virus.

Hosts: *HOMINIDAE—Homo sapiens* L., man. *SUIDAE—Sus scrofa* L., domestic swine. Experimentally, also ferret, mouse, *Macacus irus*, hedgehog, rabbit (inapparent infection), guinea pig (inapparent infection), rat (inapparent infection); *Mustela sibirica* Milne-Edwards, Chinese mink; *Sciurotamius davidianus* Milne-Edwards, David's squirrel; chick embryo (some strains produce visible lesions at 36.5° C on chorioallantoic membrane); minced chick embryo in Tyrode's solution.

Insusceptible species: *Callosciurus caniceps canigenus* Howell, Chekiang squirrel; *Eutamias asiaticus senescens* Miller, chipmunk.

Geographical distribution: World-wide.

Induced disease: In man, headache, dizziness, with shivering and muscular pains; rise of temperature on the second day, sometimes with fall on the third and elevation again later; often complicated by bronchitis and bronchopneumonia; hemorrhagic and edematous lobular consolidation in lungs; virus most easily recoverable from nasopharyngeal washings, but also from nasal secretions and lungs. In swine, virus alone produces only a mild malady (filtrate disease);

in the presence of *Haemophilus influenzae suis* a severe malady occurs under both natural and experimental conditions; it involves fever, cough, and prostration; many infected animals die. Lungworms, *Metastrongylus elongatus* and *Choerostrongylus pudendotectus* (*METASTRONGYLIDAE*), from infected swine harbor virus at least 2 years, living meantime in earthworms, such as *Allolobophora caliginosa* (*LUMBRICIDAE*), which are eaten eventually by swine. The swine are refractory to viral infection during May, June, July, and August, but the disease may be invoked later by successive intramuscular injections of *Haemophilus influenzae suis* or other stimuli, such as feeding embryonated *Ascaris* ova. In infected swine, virus occurs in turbinates, tracheal exudates, and lungs; not in spleen, liver, kidney, mesenteric lymph nodes, brain, blood, or mucosa of colon. Neutralizing antibodies appear later (7th to 10th day) in the mild filtrate disease than in typical swine influenza, in which they appear about the 6th to the 7th day; maximum titer on 14th to 27th day. Experimentally in mouse, not contagious as in swine and not dependent on the coexistence of a bacterial component; death of epithelium of respiratory and terminal bronchioles, complete epithelial desquamation, dilatation of bronchioles, collapse of alveoli; in healing, widespread epithelial proliferation. Experimentally in ferret, moderate apathy, lack of appetite, pallor of nose, variable catarrhal symptoms; at acute stage of disease, necrosis of respiratory epithelium of nasal mucous membrane, with desquamation of superficial cells, exudation into air passages and inflammatory reaction in the submucosa; repair follows, beginning on the 6th day after infection and becoming essentially complete at the end of 1 month; after recovery, the ferret is immune for 3 months or more, with subsequent waning of resistance; subsequent subcutaneous inoculations of virus restore immunity.

Transmission: Presumably by droplets; for example between cages of ferrets as close as 5 feet apart, even to levels 3 feet higher than cage of diseased individuals. Experimentally, from washings of human throats to ferret, mouse, chick embryo (by amniotic route and to allantoic membrane); in mice, by contact and by inhalation of fine droplets.

Serological relationships: Neutralizing antibodies common in human sera from individuals above 10 years of age; rarer in sera from young children; strongly effective for homologous, weak for heterologous, virus in convalescent sera. Soluble complement-fixing antigen of swine strain has components in common with antigens of human strains (PR8 and WS). Complement fixation best 10 to 14 days after onset in man. Inactivating capacity of nasal secretions proportional to level of neutralizing antibodies in blood. Agglutination of red cells by influenza virus is inhibited quantitatively by specific antiserum.

Immunological relationships: Specific immunization of ferrets, without obvious disease, occurs as a result of intranasal inoculation of egg-passage influenza virus that is not transmissible from ferret to ferret. In mice, immunizing dose is directly proportional to degree of induced immunity; immunity to the strain used in immunization is more effective in general than that to heterologous isolates of the virus.

Filterability: Passes Berkefeld V filter.

Other properties: Particle size estimated as 80 to 120 millimicrons by filtration studies; 80 to 99 millimicrons by ultracentrifugation ($S_{20°} = 724 \times 10^{-13}$ cm per sec. per dyne); electron micrographs show bean or kidney-shaped particles, or round particles with central dense spot, averaging 77.6 millimicrons in diameter. Inactivated by oleic, linolic and linolenic acids without loss of immunizing ability. Inactivated by ultraviolet radiation.

Literature: Andrewes and Glover,

Brit. Jour. Exp. Path., *22*, 1941, 91–97; Andrewes et al., *ibid.*, *16*, 1935, 566–582; Burnet, *ibid.*, *17*, 1936, 282–293; *18*, 1937, 37–43; *21*, 1940, 147–153; Austral. Jour. Exp. Biol. and Med. Sci., *14*, 1936, 241–246; *19*, 1941, 39–44, 281–290; Eaton, Jour. Bact., *39*, 1940, 229–241; Eaton and Pearson, Jour. Exp. Med., *72*, 1940, 635-643; Eaton and Rickard, Am. Jour. Hyg., *33*, (B), 1941, 23–35; Elford et al., Brit. Jour. Exp. Path., *17*, 1936, 51–53; Francis, Science, *80*, 1934, 457–459; Jour. Exp. Med., *69*, 1939, 283–300; Francis and Magill, Science, *82*, 1935, 353–354; Brit. Jour. Exp. Path., *19*, 1938, 284–293; Francis and Shope, Jour. Exp. Med., *63*, 1936, 645–653; Francis and Stuart-Harris, *ibid.*, *68*, 1938, 789–802; Francis et al., Am. Jour. Hyg., *37*, 1943, 294–300; Hirst, Jour. Exp. Med., *75*, 1942, 49–64; Hirst et al., *ibid.*, *75*, 1942, 495–511; Proc. Soc. Exp. Biol. and Med., *50*, 1942, 129–133; Horsfall and Lennette, Jour. Exp. Med., *73*, 1941, 327–333; Hudson et al., *ibid.*, *77*, 1943, 467–471; Hyde, Am. Jour. Hyg., *36* 1942, 338–353; Lennette and Horsfall, Jour. Exp. Med., *73*, 1941, 581–599; Loosli et al., Jour. Inf. Dis., *72*, 1943, 142–153; Lush and Burnet, Austral. Jour. Exp. Biol. and Med. Sci., *15*, 1937, 375–383; Magill and Francis, Brit. Jour. Exp. Path., *19*, 1938, 273–284; Nigg et al., Am. Jour. Hyg., *34* (B), 1941, 138–147; Orcutt and Shope, Jour. Exp. Med., *62*, 1935, 823-826; Rosenbusch and Shope, *ibid.*, *69*, 1939, 499–505; Shope, *ibid.*, *59*, 1934, 201–211; *62*, 1935, 561–572; *64*, 1936, 47–61; *67*, 1938, 739–748; *74*, 1941, 41–47, 49–68; *77*, 1943, 111–126, 127–138; Shope and Francis, *ibid.*, *64*, 1936, 791–801; Smillie, Am. Jour. Hyg., *11*, 1930, 392–398; Smith et al., Lancet, *225*, 1933 (*2*), 66–68; Brit. Jour. Exp. Path., *16*, 1935, 291–302; Smorodintseff and Ostrovskaya, Jour. Path. and Bact., *44*, 1937, 559–566; Stock and Francis, Jour. Exp. Med., *71*, 1940, 661–681; Straub, Jour. Path. and Bact., *45*, 1937, 75–78; Stuart-Harris, Brit. Jour. Exp. Path., *17*, 1936, 324–328; *18*, 1937, 485–492; Sulkin et al., Jour. Inf. Dis., *69*, 1941, 278–284; Tang, Brit. Jour. Exp. Path., *19*, 1938, 179–183; Taylor, (A. R.), et al., Jour. Immunol., Virus Res. and Exp. Chemother., *47*, 1943, 261–282; Taylor, (R. M.), et al., Am. Jour. Hyg., *31*, (B), 1940, 36–45; Jour. Inf· Dis., *68*, 1941, 90–96; Wells and Brown, Am. Jour. Hyg., *24*, 1936, 407–413.

2. **Tarpeia beta** *spec. nov.* From second letter of Greek alphabet.

Common name: Influenza B virus.

Hosts: *HOMINIDAE—Homo sapiens* L., man. Experimentally, also ferret, mouse, chick embryo.

Geographical distribution: United States, England.

Induced disease: In man, subclinical disease or one resembling that induced by influenza A virus. In chick embryo, experimentally, virus increases in entodermal cells lining allantoic cavity.

Serological relationships: Not neutralized by antiserum to influenza A virus. Specific neutralization and complement-fixation reactions. Rapidly adsorbed by normal chicken-blood red cells (95 per cent in 15 minutes); released in 4 hours essentially completely; the process is then repeatable with fresh red cells.

Other properties: Particle circular or bean-shaped in outline, with average diameter of 97.3 millimicrons in electron micrographs; of 99.8 millimicrons by centrifugation studies.

Literature: Burnet, Austral. Jour. Exp. Biol. and Med. Sci., *19*, 1941, 291–295; Francis, Science, *92*, 1940, 405–408; Proc. Soc. Exp. Biol. and Med., *45*, 1940, 861–863; Hirst, Jour. Exp. Med., *76*, 1942, 195–209; Lush et al., Brit. Jour. Exp. Path., *22*, 1941, 302–304; Nigg et al., Am. Jour. Hyg., *35*, 1942, 265–284; Sharp et al., Jour. Immunol., Virus Res. and Exp. Chemother., *48*, 1944, 129–153.

3. **Tarpeia premens** *spec. nov.* From Latin *premere*, to oppress or afflict.

Common name: Common-cold virus.

Hosts: *HOMINIDAE—Homo sapiens*

L., man. Experimentally, also chimpanzee, chick embryo.

Geographical distribution: World-wide except in conditions of isolation of small communities.

Induced disease: In man, incubation period about 48 hours; mild malady; running nose in 81 per cent of cases, obstruction of nostrils in 44 per cent, sudden onset in 37 per cent, cough in 31 per cent, headache in 19 per cent, sore throat in 14 per cent, fever in 13 per cent, inflammation of eyes in 12 per cent; changes in weather, especially during a warm season, predispose to the disease; no correlation between susceptibility and outdoor exercise, exposure to fresh air while sleeping, eye color, adenotonsillectomy, or size of frontal sinus. Incidence inversely proportional to daily hours of sunshine and atmospheric temperature. Fitness (defined by speed of oxygen replacement) correlated with relative freedom from colds. Effect of rest during disease favorable, reducing complications, length of fever, duration of illness, and period off duty.

Immunological relationships: After attack, specific immunity for about 7 weeks (minimum period 23 days); then exposure to chilling may cause a relapse, but an isolated community tends to lose the virus during the refractory period.

Filterability: Passes Berkefeld V and W as well as Seitz filters.

Other properties: Viable at least 13 days at ice-box temperature, anaerobically; at least 4 months frozen and dried *in vacuo*. Gum acacia tends to stabilize virus in chick-embryo tissue medium.

Literature: Dochez et al., Jour. Exp. Med., *63*, 1936, 559–579; Doull et al., Am. Jour. Hyg., *13*, 1931, 460–477; *17*, 1933, 536–561; Gafafer, *ibid.*, *13*, 1931, 771–780; *16*, 1932, 233–240, 880–884; Jour. Inf. Dis., *51*, 1932, 489–492; Gafafer and Doull, Am. Jour. Hyg., *18*, 1933, 712–726; Hyde and Chapman, *ibid.*, *26*, 1937, 116–123; Kneeland et al., Proc. Soc. Exp. Biol. and Med., *35*, 1936, 213–215; Le Blanc and Welborn, Am. Jour. Hyg., *24*, 1936, 19–24; Locke, Jour. Inf. Dis., *60*, 1937, 106–112; Long and Doull, Proc. Soc. Exp. Biol. and Med., *28*, 1930, 53–55· Maughan and Smiley, Am. Jour. Hyg., *9* 1929, 466–472; Noble and Brainard, Jour. Bact., *29*, 1935, 407–409; Palmer, Am. Jour. Hyg., *16*, 1932, 224–232; Paul and Freese, *ibid.*, *17*, 1933, 517–535; Shibley et al., Jour. Am. Med. Assoc., *95*, 1930, 1553–1556; Smiley, Am. Jour. Hyg., *6*, 1926, 621–626; *9*, 1929, 477–479.

4. **Tarpeia felis** *spec. nov.* From Latin *feles*, cat.

Common name: Feline-distemper virus.

Hosts: *FELIDAE—Felis catus* L., domestic cat; *F. pardus*, leopard; *F. tigrina*, American tiger cat; *F. aurata*, African tiger cat; *F. planiceps*, rusty tiger cat; *F. marmorata*, marbled cat; *F. caracal*, caracal lynx; *F. pardalis*, ocelot; lion, tiger, puma relatively insusceptible.

Insusceptible species: Man, dog, ferret, mongcose, rabbit, rat, mouse, guinea pig.

Induced disease: In domestic cat, coughing, sneezing, running eyes and nose, with serous or purulent conjunctivitis, or diarrhea and vomiting; fever to 103 or 105° F; loss of appetite, general weakness; mortality high, especially among young individuals; death usually occurs on the 10th to the 12th day, in extreme cases, however, as early as the 5th or as late as the 35th day; catarrhal congestion in some part of the gastro-intestinal tract is typical; this ranges from a few small patches in the ileum to involvement of the whole small intestine and parts of the large intestine or stomach and esophagus; often enlargement and congestion of abdominal lymph glands, enlargement of spleen, pleurisy, and peritonitis.

Filterability: Passes Berkefeld N and Chamberland L_3 filters.

Transmission: By fomite s.

Immunological relationships: Recovered cats specifically immune.

Other properties: Viable at least 3 weeks in 50 per cent glycerine; attenuated or killed by drying at room temperature, but some immunization is reported if dried virus is injected.

Literature: Dalling, Vet. Record, *15*, 1935, 283–289; Findlay, Vet. Jour., *89*, 1933, 17–20; Hindle and Findlay, Jour. Comp. Path. and Therap., *45*, 1932, 11–26; Verge and Cristoforoni, Compt. rend. Soc. Biol., Paris, *99*, 1928, 312–314.

5. **Tarpeia vitulae** *spec. nov.* From Latin *vitula*, cow-calf.

Common name: Pneumoenteritis virus

Hosts: *BOVIDAE—Bos taurus* L., domestic cattle. Experimentally, also *MURIDAE—Mus musculus* L., mouse.

Geographical distribution: United States.

Induced disease: In cattle (calves), after incubation period of 2 to 4 days, fever increasing rapidly to 40 or 41° C and lasting 3 to 5 days; usually after first day of fever, diarrhea with feces soft, yellow, voluminous, fetid in odor, occasionally blood-tinged or fluid; diarrhea is followed by pneumonia and recovery after disappearance of fever; catarrhal enteritis and a bronchopneumonia usually confined to the anterior lobes of the lungs underlie the symptoms; no inclusion bodies in cells of affected tissues.

Transmission: By pen contacts with infected calves. Experimentally, by intranasal inoculation of calves, using inocula prepared from lungs of infected mice.

Serological relationships: Recovered animals develop neutralizing antibodies.

Immunological relationships: A specific resistance to reinfection is conferred by an attack of the disease.

Filterability: Passes Berkefeld N filter.

Literature: Baker, Cornell Vet., *32*, 1942, 202–204; Jour. Exp. Med. *78*, 1943, 435–446.

6. **Tarpeia canis** *spec. nov.* From Latin *canis*, dog.

Common name: Canine-distemper virus.

Hosts: *CANIDAE—Canis familiaris* L., dog; *Vulpes* sp., fox. *MUSTELIDAE*—ferret.

Insusceptible species: Man, rabbit, guinea pig, white rat, cat.

Geographical distribution: Widespread throughout the world.

Induced disease: In dog, after 4 days from time of infection, fever and a watery discharge from the eyes and nose, sometimes inconspicuous but often profuse; usually diarrhea and wasting followed by recovery or, exceptionally, death. Virus passes from the respiratory tract through the blood stream to its favored sites in vascular endothelium and cells of the reticulo-endothelial system. Nuclear inclusions are found in liver cells, bronchial epithelial cells, glandular cells of the stomach and intestine, and bile-duct epithelial cells; there are also cytoplasmic inclusions in bile-duct epithelial cells.

Transmission: By contact. Probably by air-borne droplets. No arthropod vector is recognized.

Immunological relationships: Dead-vaccine treatment followed by living-virus treatment produces a lasting immunity. Virus inactivated by photodynamic effect in 2 mm layer of 1:50,000 or 1:100,000 methylene blue, exposed 30 minutes at 20 cm from 100 candle-power lamp, still immunizes. Vaccine may be dried.

Filterability: Passes Chamberland L_2 and Mandler filters.

Other properties: Viable in liver tissue at 10° C for 35, not 85, days; in glycerine-saline solution at 10° C, 67 days though deteriorated; in vacuum-dried liver tissue, at 10° C, 90 days. If dried from frozen state, virus is viable in vacuum at least 430 days at 7° C, in oxygen-free nitrogen at least 365 days at 7° C. Viable in 25 per cent sterile horse serum at −24° C more than 693 days.

Literature: Carré, Compt. rend. Acad. Sci., Paris, *140*, 1905, 689–690; Dalldorf,

Jour. Exp. Med., *70*, 1939, 19–27; De Monbreun, Am. Jour. Path., *13*, 1937, 187–212; Dunkin and Laidlaw, Jour. Comp. Path. and Therap., *39*, 1926, 201–212. 213–221; Green and Evans, Am. Jour. Hyg., *29* (B), 1939, 73–87; Laidlaw and Dunkin, Jour. Comp. Path. and Therap., *39*, 1926, 222–230; *41*, 1928, 1–17, 209–227; Perdrau and Todd, *ibid.*, *46*, 1933, 78–89; Siedentopf and Green, Jour. Inf. Dis., *71*, 1942, 253–259; Wharton and Wharton, Am. Jour. Hyg., *19*, 1934, 189–216.

7. **Tarpeia vulpis** *spec. nov.* From Latin *vulpes*, fox.

Common name: Fox-encephalitis virus.

Hosts: *CANIDAE—Vulpes* sp., silver fox. Experimentally, also some, but not all, dogs; coyote.

Insusceptible species: Gray fox, mink, ferret, sheep, laboratory rabbit.

Geographical distribution: United States.

Induced disease: In fox, after 2 days from time of infection, loss of appetite, slight nasal discharge; convulsions with early death or hyperexcitability, blind walking, lethargy, flaccid or spastic paralysis, muscular twitching, fearfulness, weakness, coma and death; many more foxes become infected in epizootics than show obvious disease, some being symptomless carriers; 12 to 20 per cent fatalities may be experienced among young foxes on ranches, 3 to 9 per cent among adults. Intranuclear inclusions in vascular endothelial cells especially in cerebral endothelium; sometimes in hepatic cells and endothelial cells of liver and kidney; no intracytoplasmic inclusions; virus in heart blood, spleen, and brain; in carriers, virus is believed to persist in focal lesions in upper respiratory tract. Experimentally in susceptible dogs, sometimes coryza, discharge from eyes and nose often purulent, commonly fits of excitement, coma, death; recovery rare; cellular infiltration in the central nervous system, focal necrosis of the liver; specific intranuclear inclusions in cells of the vascular endothelium, meningeal cells, reticulo-endothelium, hepatic cells, and occasionally in cortical cells of the adrenal.

Transmission: Experimentally, by skin scarification, intramuscular injection, intraperitoneal injection, inoculation of cisterna, intratesticular injection, inoculation of nasal cavity; not by corneal scarification.

Immunological relationships: Injections of this virus afford no immunity to subsequent infection by canine distemper virus.

Filterability: Passes Berkefeld N filter.

Other properties: Viable in 50 per cent glycerine for several years, in carcass for several days.

Literature: Barton and Green, Am. Jour. Hyg., *37*, 1943, 21–36; Green, Proc. Soc. Exp. Biol. and Med., *23*, 1926, 677–678; Am. Jour. Hyg., *13*, 1931, 201–223; Green and Dewey, Proc. Soc. Exp. Biol. and Med., *27*, 1929, 129–130; Green and Evans, Am. Jour. Hyg., *29* (B), 1939, 73–87; Green and Shillinger, *ibid.*, *19*, 1934, 362–391; Green et al., *ibid.*, *12*, 1930, 109–129; *14*, 1931, 353–373; *18*, 1933, 462–481; *19*, 1934, 343–361; *21*, 1935, 366–388; *24*, 1936, 57–70; Lucas, Am. Jour. Path., *16*, 1940, 739–760.

8. **Tarpeia viverrae** *spec. nov.* From Latin *viverra*, ferret.

Common name: Ferret-distemper virus.

Host: *MUSTELIDAE—Mustela furo*, ferret.

Insusceptible species: Dog, mouse, rat, guinea pig, rabbit.

Geographical distribution: United States.

Induced disease: In ferret, fever to 105 or 106° F, lethargy, loss of appetite, conjunctivitis with exudate closing eyes, sometimes a purulant nasal discharge, weight loss small, sneezing rare, difficulty in breathing, death 14 to 56 days after inoculation (average 20 days), sometimes

preceded by convulsions and other nervous signs; fatality rate 70 to 100 per cent.

Transmission: By cage contacts. By feeding. Experimentally by intranasal, subcutaneous, or intradermal inoculation.

Immunological relationships: In immunized animals, no cross immunity with canine distemper virus nor with human influenza virus.

Thermal inactivation: At 60° C in 30 minutes.

Filterability: Passes Berkefeld N filter.

Other properties: Viable at least 3, but not 5, months in 50 per cent neutral glycerine; at least 4 months when frozen and dried *in vacuo*.

Literature: Slanetz and Smetana, Jour. Exp. Med., *66*, 1937, 653–666; Spooner, Jour. Hyg., *38*, 1938, 79–89.

9. **Tarpeia avium** *spec. nov.* From Latin *aves*, fowl of the air.

Common names: Laryngotracheitis virus; also known as infectious laryngotracheitis virus and as infectious bronchitis virus.

Hosts: *PHASIANIDAE—Gallus gallus* (L.), chicken. Experimentally, also *PHASIANIDAE*—pheasant; F_1 hybrid between male Ringneck pheasant and female bantam chicken; chorioallantoic membrane of developing chicken embryo (with macroscopic lesions on membrane as a result of proliferative and necrotic changes); turkey embryo.

Insusceptible species: Guinea fowl (no evidence of disease on inoculation); white rat, guinea pig, rabbit; embryos of pigeon, guinea fowl, and duck.

Geographical distribution: United States, Canada, Australia.

Induced disease: In domestic chicken, mostly among pullets and yearling hens, loss of appetite, lachrymation from one or both eyes, respiratory distress, hemorrhagic and mucous exudate in lumen of trachea and occasionally in the bronchi; death as a result of asphyxiation or, more often, recovery; recovered birds occasionally carry the virus in the upper respiratory tract for some time (a period of 467 days has been recorded); virus is not found on eggs during an outbreak in a flock, but is always in trachea of an affected bird; intranuclear inclusions in tracheal lesions; virus has special affinity for mucous membrane of eye, nostril, larynx, trachea, cloaca, and bursa of Fabricius; usually affects more than half the birds in a flock, with a mortality of 5 to 60 per cent (averaging between 10 and 20 per cent).

Transmission: By contacts. Experimentally, by intrabursal injection (in bursa of Fabricius) or by rubbing the mucous membrane in the dorsal region of the outer or proctodeal part of the cloaca with a small cotton swab moistened with a suspension of virus.

Serological relationships: Serum from recovered fowl neutralizes virus; dilution tends to reactivate neutralized virus.

Immunological relationships: Experimental infection of cloaca and bursa of Fabricius, especially in 2 to 4-month-old birds, immunizes against infection by subsequent tracheal inoculation.

Thermal inactivation: At 55.5° C in 10 to 15 minutes; at 60° C in 2 to 3 minutes; at 75° C in ¼ to ½ minute; all tests with virus in the presence of tracheal exudate.

Filterability: Passes Berkefeld V and N filters.

Strains: A Victorian strain has been reported as of low virulence for fowls.

Other properties: Inactivated in 5 per cent phenol in 1 minute; in 3 per cent cresol compound in ½ minute; in 1 per cent sodium hydroxide in ½ minute. Viable in tracheal fluid in dark for 75, not 110, days; in light for 6, not 7, hours; in buffer solution at pH 7.4 for 131 days; at 4 to 10° C in dark for at least 217 days; in dried state for at least 661 days. Viable in dead body at 37° C for 22, not 44, hours; at 13 to 23° C for 10, not 15, days; at 4 to 10° C for 30, not 60, days.

Literature: Beach, Science, *72*, 1930, 633–634; Jour. Exp. Med., *54*, 1931, 809–816; Jour. Inf. Dis., *57*, 1935, 133–135;

Beach et al., Poultry Science, *13*, 1934, 218–226; Beaudette and Hudson, Science, *76*, 1932, 34; Jour. Am. Vet. Med. Assoc., *82* (N.S. *35*), 1933, 460–476; *95*, 1939, 333–339; Brandly, *ibid.*, *88* (N.S. *41*), 1936, 587–599; Jour. Inf. Dis., *57*, 1935, 201–206; Brandly and Bushnell, Poultry Science, *13*, 1934, 212–217; Burnet, Brit. Jour. Exp. Path., *15*, 1934, 52–55; Jour. Exp. Med., *63*, 1936, 685–701; Burnet and Foley, Austral. Jour. Exp. Biol. and Med. Sci., *19*, 1941, 235–240; Gibbs, Jour. Am. Vet. Med. Assoc., *81*, (N.S. *34*), 1932, 651–654; Massachusetts Agr. Exp. Sta., Bull. 295, 1933, *ibid.*, Bull. *311*, 1934; Hinshaw et al., Poultry Science, *10*, 1931, 375–382; Hudson and Beaudette, Science, 76, 1932, 34; Cornell Vet., *22*, 1932, 70–74; Kernohan, California Agr. Exp. Sta., Bull. 494, 1930, 3–22; Jour. Am. Vet. Med. Assoc., *78* (N.S. *31*), 1931, 553–555; Komarov and Beaudette, Poultry Science, *11*, 1932, 335–338; May and Tittsler, Jour. Am. Vet. Med. Assoc., *67*, (N.S. *20*), 1925, 229–231; Schalm and Beach, Jour. Inf. Dis., *56*, 1935, 210–223; Seifried, Jour. Exp. Med., *54*, 1931, 817–826.

Genus III. Tortor *gen. nov.*

Viruses of the Hog-Cholera Group, inducing diseases characterized by involvement of many tissues. Generic name from Latin *tortor*, tormentor.

The type species is *Tortor suis spec. nov.*

Key to the species of genus Tortor.

I. In mammals.
  A. Infecting swine.
    1. *Tortor suis.*
  B. Infecting cattle.
    2. *Tortor bovis.*
  C. Infecting the horse.
    3. *Tortor equorum.*
    4. *Tortor equae.*
  D. Infecting sheep.
    5. *Tortor ovis.*
  E. Infecting cat.
    6. *Tortor felis.*

II. In birds.
    7. *Tortor galli.*
    8. *Tortor furens.*

1. **Tortor suis** *spec. nov.* From Latin *sus*, hog.

Common names: Hog-cholera virus, swine-fever virus.

Host: *SUIDAE—Sus scrofa* L., domestic swine. Warthog (symptomless carrier).

Insusceptible species: Dog, cat, cow, horse, donkey, sheep, goat, rabbit, guinea pig, mouse, rat, goose, hen, duck, pigeon.

Geographical distribution: Almost universal in pig-breeding countries, especially in Europe, the British Isles, North and South America.

Induced disease: In swine, after intramuscular injection, increased temperature and prostration within $2\frac{1}{2}$ to 3 days; later lymph nodes enlarged, sometimes hemorrhagic; hemorrhages under capsule of kidneys. Virus may remain in blood of recovered pigs for 10 months. Acquired immunity is lasting, but most naturally infected animals die in newly infected herds. Virus has been cultured

in minced swine testicle on solid serum-agar and on egg membrane, increase being limited to the living tissues from the swine and furnishing inoculum active in amounts as small as 10^{-5} ml.

Transmission: By feeding. Through air contamination. Rarely by contact. Experimentally, by subcutaneous injection. Urine highly infective. Virus in blood and all tissues early in disease.

Serological relationships: Immune serum affords passive protection.

Thermal inactivation: At 55° C in 30 minutes; at 60° C in 10 minutes. At 72° C in 1 hour in dried blood.

Filterability: Passes Berkefeld filter.

Other properties: Viable in blood in cool, dark place at least 6 years.

Literature: De Kock et al., Onderstepoort Jour. Vet. Sci. and Anim. Indust., *14*, 1940, 31–93; Hecke, Cent. f. Bakt., I Abt., Orig., *126*, 1932, 517–526; Montgomery, Jour. Comp. Path. and Therap., *34*, 1921, 159–191; Röhrer, Arch. Tierheilk., *62*, 1930, 345–372, 439–462; *64*, 1931, 124–143; TenBroeck, Jour. Exp. Med., *74*, 1941, 427–432.

2. **Tortor bovis** *spec. nov.* From Latin *bos*, cow.

Common names: Cattle-plague virus, virus of pestis bovina, runderpest virus, Rinderpest virus.

Hosts: *BOVIDAE—Bos taurus* L., domestic cattle; swine, buffalo, zebu cattle, sheep, goat, camel, deer. Koedoe, eland, bushbuck, duiker, and other antelopes.

Insusceptible species: Man, solipeds, carnivora.

Geographical distribution: Widespread over Asia and the Asiatic islands. At times in Western Europe. Enzootically in Turkey. Periodically in North Africa, especially in Egypt; at times throughout Africa. Not in North America. At times in South America, Australia (suppressed quickly).

Induced disease: In domestic cattle, after 3 to 9 days, febrile reaction, restlessness, loss of appetite, cessation of rumination; fever highest at 5th or 6th day of disease, then temperature drops to normal or subnormal and diarrhea begins; muzzle dry, coat staring, hair dull, skin moist in parts; twitching of superficial muscles, grinding of teeth, arching of back, glairy discharge from nose, redness of mucous membranes; restlessness increases, diarrhea becomes severe with fetid, blood-stained or blackish liquid discharges; weakness, drooping of ears, occasional yawning, coldness of extremities; occasionally excitement precedes weakness; skin may become red and moist, showing protuberances and vesicles, with matted hair; later wrinkling and scab formation; conjunctiva red, eyelids swollen, tears flowing, followed by mucous, then purulent, discharge; sometimes a cough develops and respirations become rapid; red spots inside mouth develop into erosions or ulcers, often confluent; pregnant animals often abort; milk of cows decreases, sometimes becoming yellow and watery. Death is sometimes early (1 to 2 days after first manifestations of disease), more often delayed (4 to 7 days); sometimes animals live 2 or 3 weeks or longer. Disease milder and more chronic where enzootic; morbidity to 100 per cent and mortality to 96 per cent in new areas. Recovered animals show a lasting, sterile mmunity. Urine, feces, nasal and lachrymal discharges, sweat, aqueous humour, cerebrospinal fluid, lymph, emulsions of viscera and muscles, and blood are infective during the course of the disease.

Transmission: By contact, even during prodromal period; by contaminated food, troughs, or other articles. No insect vector is known.

Immunological relationships: One attack confers a lasting immunity, except rarely, when a mild second attack may occur. A calf from a diseased mother may be resistant if pregnancy was far advanced when the disease occurred.

Filterability: Passes Berkefeld V filter candle, with difficulty.

Other properties: Remains infective at

least 2 weeks at 0° C in virulent blood, less than 2 days in hides dried in direct sunlight, 3 days in contaminated wool, as long as 12 days in meat; is inactivated by glycerine, bile, chloroform, formalin, and 2 per cent phenol; is virulent at least 25 days in body of leech, *Hirudo boyntoni* Wharton (*HIRUDIDAE*), fed on sick animal.

Literature: Boynton, Philippine Agr. Rev., *10*, 1917, 410–433; Daubney, Jour. Comp. Path. and Therap., *41*, 1928, 228–248; 263–297; Hornby, *ibid.*, *41*, 1928, 17–24; Pfaff, Onderstepoort Jour. Vet. Sci. and Anim. Indust., *11*, 1938, 263–330; *15*, 1940, 175–184; Weston, Jour. Am. Vet. Med. Assoc., *66* (N.S. *19*), 1924, 337–350.

3. **Tortor equorum** *spec. nov.* From Latin *equus*, horse.

Common names: Horse-sickness virus, African horse-sickness virus, virus of pestis equorum, virus of perdesiekte, virus of South African Pferdesterbe.

Hosts: *EQUIDAE—Equus caballus* L., horse; perhaps *E. asinus* L., donkey. Experimentally, also *CANIDAE—Canis familiaris* L., dog. *CAVIIDAE—Cavia porcellus* (L.), guinea pig. *MURIDAE—Rattus norwegicus* (Erxleben), wild and albino rat; mouse; Angora goat; *Mastomys coucha*, multimammate mouse; *Tatera lobengula*, gerbille; chick embryo (but no virus in hatched chick). Mule and zebra relatively resistant.

Insusceptible species: *HOMINIDAE—Homo sapiens* L., man. *LEPORIDAE—Oryctolagus cuniculus* (L.), rabbit (no observed disease).

Geographical distribution: Africa, especially in coastal regions and river valleys.

Induced disease: In the horse, four types of disease are recognized. Horse-sickness fever, prodromal period 5 to 28 days, rise of body temperature to 105° F in 1 to 3 days, with return to normal temperatures in another day or two; sometimes loss of appetite, redness of conjunctiva, labored breathing, and accelerated pulse; recovery prompt. Dunkop or acute pulmonary horse-sickness, prodromal period of 3 to 5 days, severe dyspnea, fever, coughing, frothing at nostrils; fever to 106° F, breathing rate to 60 a minute, nostrils dilated, head and neck extended, ears drooping, sweating, progressive weakness; often fatal. Dikkop, or cardiac form of horse-sickness, prodromal period 5 to 21 days, fever develops slowly, lasts long; edematous swellings of head and neck, symptoms of cardiac dyspnea, sometimes blood spots on conjunctiva, mucous membranes of mouth and tongue bluish, restlessness; sometimes fatal outcome. Mixed form of horse-sickness, combining features of pulmonary and cardiac types. Horses recovering from natural infections are known as "salted" and possess heightened resistance to the disease.

Transmission: Not by contact. Mosquitoes and biting flies have been suspected as vectors. Experimentally, by intravenous or subcutaneous injection.

Serological relationships: Serologically distinguishable strains exist.

Immunological relationships: Immunity to homologous strain complete after an attack (horse then known as "salted" for that strain), but immunity to heterologous strains incomplete. Antibodies absent from young at birth but as high in titer as in dam within 30 hours, presumably from colostral milk; declining gradually over a period of about 6 months.

Thermal inactivation: At 57.5 to 60° C in 10 minutes.

Filterability: Passes Berkefeld, Chamberland F, and Seitz EK filters.

Other properties: Viable dry at least 15 months. Stable in alkaline solutions (to pH 10), unstable in acid (beyond pH 6.0). Serum-saline solutions preferable to saline solutions for storage. Particle diameter determined as 40 to 60 millimicrons (mean 50 millimicrons) by filtration methods, 45.4 millimicrons by centrifuging. Density 1.25 gm per ml. Isoelectric point at pH 4.8.

Literature: Alexander, Onderstepoort Jour. Vet. Sci. and Anim. Indust., *4*, 1935, 291–322, 323–348, 349–377, 379–388; *7*, 1936, 11–16; *11*, 1938, 9–19; Alexander and DuToit, *ibid.*, *2*, 1934, 375–391; Alexander and Mason, *ibid.*, *16*, 1941, 19–32; Alexander et al., *ibid.*, *7*, 1936, 17–30; DuToit et al., *ibid.*, *1*, 1933, 21–24, 25–50; Henning, in Animal Diseases in South Africa, Central News Agency, Limited, South Africa, *2*, 1932, 516–538; M'Fadyean, Jour. Comp. Path. and Therap., *13*, 1900, 1–20; *23*, 1910, 27–33, 325–328; Nieschulz and DuToit, Onderstepoort Jour. Vet. Med. and Anim. Indust., *8*, 1937, 213–268; Polson, *ibid.*, *16*, 1941, 33–50, 51–66; Nature, *148*, 1941, 593–594; Theiler, Deutsch. tierärztl. Wochenschr., *9*, 1901, 201–203, 221–226, 233–237, 241–242; Report for 1905–1906 of the Govt. Veterinary Bacteriologist, Transvaal Dept. Agr., 1907, 160–162; Jour. Comp. Path. and Therap., *23*, 1910, 315–325.

4. **Tortor equae** *spec. nov.* From Latin *equa*, mare.

Common name: Mare-abortion virus.

Hosts: *EQUIDAE—Equus caballus* L., horse. Experimentally, also Syrian hamster (newborn); tissues of human placenta grafted on the chorioallantois of the chick embryo.

Insusceptible species: Chicken (embryo; no observed susceptibility).

Induced disease: In horse, small, multiple, grayish white areas of necrosis in the livers of aborted fetuses; acidophilic intranuclear inclusions in hepatic cells around these foci, in epithelial cells of bile ducts, and in bronchial epithelium; petechial hemorrhages in the heart, spleen, and lungs; excess fluid in the thoracic cavity.

Transmission: By contact. By living in contaminated stalls.

Literature: Anderson and Goodpasture, Am. Jour. Path., *18*, 1942, 555–561; Dimock, Jour. Am. Vet. Med. Assoc., *96*, 1940, 665–666; Dimock and Edwards, Cornell Vet., *26*, 1936, 231–240; Goodpasture and Anderson, Am. Jour. Path., *18*, 1942, 563–575; Hupbauer, Münch. Tierärztl. Wchnschr., *89*, 1938, 37–38; Miessner and Harms, Deutsche Tierärztl. Wchnschr., *46*, 1938, 745–748.

5. **Tortor ovis** *spec. nov.* From Latin *ovis*, sheep.

Common name: Blue-tongue virus.

Hosts: *BOVIDAE—Ovis aries* L., sheep; *Bos taurus* L., cattle.

Geographical distribution: South Africa.

Induced disease: Both sheep and cattle may carry the virus at times without obvious manifestations of disease or there may be severe manifestations. In sheep, experimentally, diffuse hyperemia of buccal mucosa, especially of lips; then petechiae and ecchymoses followed by excoriations and necrosis of the mucous membrane, especially on lips, tongue, inside of cheeks, dental pad, gums, muzzle, and external nares; sometimes deep seated necrotic ulcers on tongue developing from the more usual superficial necrotic process; mucoid discharge from nostrils, becoming muco-hemorrhagic; commonly frothing at the mouth in early stages of the disease; frequently reddening of skin of lips and nose; rarely whole skin becomes flushed and wool is shed; often swelling of vulva with necrotic changes on borders and petechiae in mucosa; tongue sometimes swollen; lameness common and severe; recovery or death. In cattle, edema of lips and tongue; hyperemia of oral mucosa; multiple hemorrhages in skin, lips, mucous membrane of the lips, tongue, dental pad, buccal cavity, small intestine, myocardium, epicardium, and endocardium, less frequently in the trachea, nasal cavity, bladder, urethra, pulmonary artery, and pleura; localized necrotic areas followed by ulceration on lips, gums, the dental pad, tongue, mucous membrane of the rumen, pylorus of the stomach, and the external nares; scattered skin lesions with reddening, slight exudation, crusting, sloughing of crusts and hair together,

mucoid or mucopurulent discharge from nostrils; prognosis favorable in mild cases, but disease occasionally terminates with death.

Transmission: Not by contact; arthropod vector suspected.

Other properties: Infective particle calculated to be 87 to 105 millimicrons in diameter by sedimentation studies, 100 to 132 millimicrons in diameter by ultrafiltration.

Literature: Bekker et al., Onderstepoort Jour. Vet. Sci. and Anim. Indust., *2*, 1934, 393–507; De Kock et al., *ibid.*, *8*, 1937, 129–180; Henning, in Henning, M. W., Animal Diseases in South Africa, Central News Agency, Ltd., South Africa, 1932, vol. *2*, chapter 27, pages 503–515; Mason and Neitz, Onderstepoort Jour. Vet. Sci. and Anim. Indust., *15*, 1940, 149–157; Nieschulz et al., *ibid.*, *2*, 1934, 509–562; Polson, Nature, *148*, 1941, 593–594.

6. **Tortor felis** *spec. nov.* From Latin *feles*, cat.

Common names: Panleucopenia virus, infectious feline agranulocytosis virus, infectious aleucocytosis virus, feline enteritis virus.

Host: *FELIDAE—Felis catus* L., domestic cat.

Insusceptible species: White mouse, guinea pig, domestic rabbit, ferret; *Citellus richardsonii* (Sabine), ground squirrel.

Geographical distribution: United States, Germany.

Induced disease: In cat, variable effects, some individuals little affected, others listless, recumbent, refusing food, showing some vomiting, diarrhea, nasal and ocular discharges; often death, after a few minutes of fibrillary twitching and terminal clonic convulsions, before there is much loss of weight; sometimes recovery with return of appetite. Profound leucopenia and marked relative lymphocytosis without thrombopenia or appreciable anemia; proliferation of reticulo-endothelial cells of lymph nodes and spleen; intranuclear inclusion in cells of gastro-intestinal mucosa, spleen, lymph nodes, bone marrow, and bronchial mucosa.

Transmission: Perhaps by nasal droplets or contaminated food. No arthropod vector recognized. Experimentally by oral, intragastric, cutaneous, subcutaneous, intraperitoneal, intravenous, and intranasal routes.

Serological relationships: Sera from panleucopenia-immune cats protects against agranulocytosis virus.

Immunological relationships: Cats immune as a result of earlier infection with agranulocytosis virus resist later inoculation with panleucopenia virus. Previous inoculation ineffective if made with hog-cholera virus or fox-encephalitis virus.

Filterability: Passes Berkefeld V, N, and W filters and Seitz EK discs.

Other properties: Remains active in 50 per cent glycerine at least 138 days in tissues; not inactivated by drying while frozen, nor by freezing at about −80° C.

Literature: Hammon and Enders, Jour. Exp. Med., *69*, 1939, 327–352; *70*, 1939, 557–564; Kikuth et al., Cent. f. Bakt., I Abt., Orig., *146*, 1940, 1–17; Lawrence and Syverton, Proc. Soc. Exp. Biol. and Med., *38*, 1938, 914–918; Lawrence et al., Jour. Exp. Med., *77*, 1943, 57–64; Am. Jour. Path., *16*, 1940, 333–354; Syverton et al., Jour. Exp. Med., *77*, 1943, 41–56.

7. **Tortor galli** *spec. nov.* From Latin *gallus*, cock.

Common names: Fowl-plague virus, fowl-pest virus.

Hosts: Chiefly chicken, turkey, goose. Experimentally, also ferret, rhesus monkey, hedgehog, pigeon, duck, canary, mouse, rat, rabbit. Multiplies in embryonated hen's egg; edema, but no discrete primary lesions in chorioallantoic membrane.

Geographical distribution: Widespread throughout Europe, North and South America, Asia.

Induced disease: In chicken, loss of appetite, tendency to leave companions

and seek shade, drooping of wings and tail; eyes closed or partly closed; some dyspnea; in some cases, edema of head and neck; in late stages, sometimes cyanosis of comb and skin; staggering, twitching, or spasms; fever may disappear and temperature become subnormal before death; recovery in about 30 per cent of all cases; linear and punctiform hemorrhages throughout body.

Transmission: Method of natural transmission unknown. The fowl louse, *Goniodes dissimilis* (*PHILOPTERIDAE*), has been suspected as vector (Maggiora and Tombolato, Rendiconti, Accademia delle Scienze dell'Instituto di Bologna, n.s. *27*, 1923, 200–203). Experimentally, by subcutaneous, intramuscular, and intravenous injection.

Serological relationships: Specific neutralizing antiserum does not react with influenza virus. No reaction of fowl-plague virus with antisera specific for canine distemper, influenza, or Rift Valley fever viruses.

Thermal inactivation: At 55° C in 1 hour in whole blood or brain.

Filterability: Passes membrane of average pore diameter 150, not 100, not ordinarily 125, millimicrons. Passes Berkefeld and Chamberland filters.

Other properties: Particle diameter estimated by filtration as 60 to 90 millimicrons; by centrifugation, as 120 to 130 millimicrons. Viable after exposure in 1:10,000 dilution for 10 minutes, in 2 mm layer of 1:50,000 methylene blue, 15 cm from a 300 candle-power filament lamp. Withstands drying. Precipitates from salt-free solutions or in presence of half-saturated ammonium sulphate solutions; virus held to be of globulin nature by Mrowka, Cent. f. Bakt., I Abt., Orig., *67*, 1912, 249–268.

Strains: Variant strains have been produced by intracerebral passage in brains of canaries and mice.

Literature: Bechhold and Schlesinger, Biochem. Ztschr., *236*, 1931, 387–414; Ztschr. Hyg. Infektionskr., *112*, 1931, 668–679; Burnet and Ferry, Brit. Jour. Exp. Path., *15*, 1934, 56–64; Centanni, Cent. f. Bakt., I Abt., Orig., *31*, 1902, 145–152, 182–201; Elford and Todd, Brit. Jour. Exp. Path., *14*, 1933, 240–246; Findlay and Mackenzie, *ibid.*, *18*, 1937, 146–155, 258–264; Findlay et al., Jour. Path. and Bact., *45*, 1937, 589–596; Lépine Compt. rend. Soc. Biol., Paris, *121*, 1936, 509–510; Mackenzie and Findlay, Brit. Jour. Exp. Path., *18*, 1937, 138–145; Nieschulz and Bos, Cent. f. Bakt., I Abt., Orig., *131*, 1934, 1–6; Plotz and Haber, Compt. rend. Soc. Biol., Paris, *125*, 1937, 339–340.

8. **Tortor furens** *spec. nov.* From Latin *furere*, to rage.

Common name: Newcastle-disease virus.

Hosts: *PHASIANIDAE—Gallus gallus* (L.), domestic chicken. *HOMINIDAE—Homo sapiens* L., man (by laboratory accident). Experimentally, also pigeon; chick embryo (with primary lesions and cytoplasmic inclusions in chorioallantoic membrane).

Geographical distribution: England, probably also East Indies, Korea, Japan, India, Australia.

Induced disease: In chicken, acute, febrile, highly contagious, usually fatal disease resembling fowl plague; loss of appetite, crouching attitude, half closed eyes, rapid respirations, watery yellowish-white diarrhea with nauseating odor; death usually between 6th and 8th day. In man, accidentally infected in laboratory by virus sprayed into eye, virus recoverable from temporarily inflamed eye; recovery in 8 days with gradual increase of specific antibodies in blood.

Transmission: By contact between healthy and diseased birds.

Serological relationships: Antiserum effective in neutralizing homologous virus.

Immunological relationships: Chickens immune to infection by fowl-plague virus are susceptible to infection by this virus

and *vice versa*. Immunization to this virus does not decrease susceptibility to comb or mouth form of fowl pox.

Thermal inactivation: At 60° C in 1 hour; not at 56° C in 30 minutes.

Filterability: Passes Berkefeld, Chamberland L_3, and Seitz filters.

Other properties: Particle diameter calculated from filtration experiments to be 80 to 120 millimicrons. Not inactivated in 30 minutes in 1:50,000 methylene blue solution in 2 mm layer 15 cm from a 300 candle-power filament lamp.

Literature: Burnet, Med. Jour. Australia, *30*, 1943, 313–314; Burnet and Ferry, Brit. Jour. Exp. Path., *15*, 1934, 56–64; Doyle, Jour. Comp. Path. and Therap., *40*, 1927, 144–169.

FAMILY V. TRIFURACEAE *FAM. NOV.*

Viruses of the Infectious Anemia Group, inducing diseases mainly characterized by disturbances in balance of blood cells. There is a single genus.

Genus **Trifur** *gen. nov.*

With characters of the family. Generic name from Latin *trifur*, arrant thief. The type species is *Trifur equorum spec. nov.*

Key to the species of genus **Trifur.**

I. Affecting horse.

1. *Trifur equorum.*

II. Affecting fowl.

2. *Trifur gallinarum.*

1. **Trifur equorum** *spec. nov.* From Latin *equus*, horse.

Common name: Equine infectious-anemia virus.

Hosts: *EQUIDAE—Equus caballus* L., horse; *E. asinus* L., donkey. *HOMINIDAE—Homo sapiens* L., man. Experimentally, also *EQUIDAE—Equus asinus* × *E. caballus*, mule. *SUIDAE—Sus scrofa* L., swine.

Insusceptible species: *BOVIDAE—Bos taurus* L., cattle; *Ovis aries* L., sheep; *Capra hircus* L., goat. *CANIDAE—Canis familiaris* L., dog.

Geographical distribution: Europe, Union of South Africa, United States, Canada, Japan; at times in most parts of the world; not Australia.

Induced disease: In horse, progressive anemia with eventual death or clinical recovery and retention of virus; disease may be acute, subacute, or chronic; in acute disease, temperature rise to 104 to 105° F. or even 106 to 107° F, remaining high much of the time until death or change to subacute or chronic form; in the acute form of the disease there is dullness, decreased appetite, drooping of head, flexing of limb not supporting weight; sometimes increase in pulse frequency to 70 or even 100 a minute but oftener rates around 50 a minute; conjunctiva sometimes colored orange, with injection of vessels and petechiae, later becoming muddy colored or pale red, membrane edematous; uncertain gait, trailing of hind feet, prostration, sometimes death; subacute disease milder and with remissions; chronic disease still milder, anemia conspicuous, sometimes death from debility or at end of a febrile attack; blood infective long (3 to 7 years) after clinical recovery; urine infective to horse by mouth. In man, diarrhea alternating with constipation, herpes-like exanthema on abdominal wall, blood sometimes in feces; persistent headache, temperature normal; later, lumbar pains, generalized edema, general debility, loss of flesh, pallor of face and mucosae; filtered blood in 1 ml. amount fatal to horse, inducing infectious anemia; improvement after 2 to 4 years. In swine, experimentally, sometimes no outward and obvious signs of disease but blood abnormal and infective; sometimes severe anemia, fever, prostration, loss of appetite.

Thermal inactivation: At 58 to 60° C in 1 hour.

Filterability: Passes Berkefeld V filter candle.

Other properties: Viable in blood in citrate saline at −2° C for at least a year. Drying does not inactivate in 10 days but does in 1 month.

Literature: DeKock, Union of South Africa, Dept. of Agr., 9th and 10th Reports for 1923, Pretoria 1924, 253–313; Habersang, Monatshefte für prakt. Tierheilk., *30*, 1920, 171–176; Kutsche, *ibid.*, *30*, 1920, 557–568; Peters, Jour. Am. Vet.

Med. Assoc., *66*, 1924, 363–366; Theiler and Kehoe, Union of South Africa, Dept. of Agr., 3rd and 4th Reports of the Director of Veterinary Research, 1915, 215–289.

2. **Trifur gallinarum** *spec. nov.* From Latin *gallina*, hen.

Common name: Fowl-leucosis virus.

Host: *Gallus gallus* (L.), chicken.

Geographical distribution: United States, England, Europe.

Induced disease: In chicken, neurolymphomatosis, with eye lesions (slate gray or bluish color replacing normal bay color of iris), anemia, hemocytoblastosis, lymphoid, erythroid or myeloid types of leucosis; the hemocytoblastosis is followed by infiltration of the central nervous system, peripheral nerves, iris, and many visceral organs by hemocytoblasts and lymphocytes, producing lesions sometimes resembling neoplasms and consisting chiefly of hemocytoblasts (hemocytoblastomata); marrow of radius and ulna becomes hyperplastic; virus in blood plasma, blood cells, emulsions of organs; blood normal in its hydrogen-ion concentration; recovery never complete; some stocks less susceptible than others.

Transmission: By pen contact or contaminated litter. Experimentally by intravenous injection of cell-free filtrates. Not by the mosquitoes, *Culex pipiens* and *Aëdes aegypti* (*CULICIDAE*). Day-old chicks from iritis parents contain the infective agent and show some form of the induced disease in 80 per cent of the progeny if both parents show iritis, in 70 per cent if male is normal, 15 per cent if female is normal.

Serological relationships: Specific neutralizing antibodies are formed in the rabbit as a result of injecting infective materials partly purified by sedimentation in the ultracentrifuge.

Thermal inactivation: At 56° C in 30 minutes.

Filterability: Passes Berkefeld V, N, and W filter candles; 1.5 per cent, but not often 3 per cent, collodion membranes; Seitz asbestos filter.

Other properties: Viable after drying at least 54 days, in glycerine at least 104 days, at 4° C at least 14 days, at −60° C at least 6 months; after freezing and thawing, and after freezing in liquid air. Not viable after 14 days at 37.5° C. Particle diameter between 100 and 400 millimicrons.

Literature: Ellermann and Bang, Cent. f. Bakt., I Abt., Orig., *46*, 1908, 4–5, 595–609; Furth, Proc. Soc. Exp. Biol. and Med., *27*, 1929, 155–157; Jour. Exp. Med., *53*, 1931, 243–267; *55*, 1932, 465–478, 495–504; *58*, 1933, 253–275; *59*, 1934, 501–517; Furth and Miller, *ibid.*, *55*, 1932, 479–493; Hall et al., Am. Jour. Vet. Res., *2*, 1941, 272–279; Jármai, Arch. wissensch. u. prakt. Tierhielk., *62*, 1930, 113–131; Johnson, Virginia Agr. Exp. Sta. Tech. Bull. *56*, 1934, 1–32; Johnson and Bell, Jour. Inf. Dis., *58*, 1936, 342–348; Kabat and Furth, Jour. Exp. Med., *71*, 1940, 55–70; *74*, 1941, 257–261; Lee and Wilcke, Am. Jour. Vet. Res., *2*, 1941, 292–294; Lee et al., Jour. Infect. Dis., *61*, 1937, 1–20; Pierce, Am. Jour. Path., *18*, 1942, 1127–1139; Ratcliffe and Stubbs, Jour. Inf. Dis., *56*, 1935, 301–304.

FAMILY VI. RABULACEAE *FAM. NOV.*

Viruses of the Mumps Group, characterized in general by a special affinity for tissues of the salivary glands. There is a single genus,

Genus I. **Rabula** *gen. nov.*

With characters of the family. Generic name from Latin *rabula*, pettifogger. The type species is *Rabula inflans spec. nov.*

Key to species of the genus **Rabula.**

I. Affecting man.
  1. *Rabula inflans.*

II. Affecting guinea pig.
  2. *Rabula levis.*

III. Affecting hamster.
  3. *Rabula innocuus.*

IV. Affecting rat.
  4. *Rabula exiguus.*

V. Affecting mouse.
  5. *Rabula latens.*

1. **Rabula inflans** *spec. nov.* From Latin *inflare*, to puff up.

Common names: Mumps virus, virus of epidemic parotitis.

Hosts: *HOMINIDAE—Homo sapiens* L., man. Experimentally, also *CERCOPITHECIDAE—Macaca mulatta* (Zimmermann), rhesus monkey. *FELIDAE —Felis catus* L., domestic cat.

Geographical distribution: World-wide.

Induced disease: In man, in order of frequency, parotitis, orchitis, meningo-encephalitis, pancreatitis, or ovaritis; rarely fatal; when parotitis occurs, onset is sudden, with pain in one or both parotid glands, sometimes also with involvement of submaxillary and sublingual glands, swelling and malaise gradually disappearing within a week or 10 days; there is virus in saliva 48 hours after onset; orchitis, less common, is usually unilateral and may be accompanied by some epididymitis. In rhesus monkey, experimentally, acute, non-suppurative parotitis; focal necrosis in acinar epithelial cells of parotid gland, and secondary inflammation; dissemination of lesions within the gland, enlargement of gland to palpation and pitting edema of jowl 6 to 8 days after inoculation, often with a rise of temperature; cytoplasmic inclusion bodies affected glands, staining pink, round or oval, 3 to 10 microns in diameter, often vacuolate, usually surrounded by a narrow clear zone in the cytoplasm; blood and uninoculated salivary gland of affected animal not effective sources of virus.

Transmission: Probably by droplets arising directly from infected individuals. Experimentally, by injecting sterile fluids containing virus into Stenson's duct of parotid gland in *Macaca mulatta.*

Serological relationships: A specific complement-fixing antibody occurs in human and monkey convalescent serum and is demonstrable by the use of monkey-gland antigen.

Immunological relationships: Specific immunity induced by attack; passive immunization rarely successful.

Thermal inactivation: At 55° C in 1 hour.

Filterability: Passes Berkefeld V and N filter candles.

Other properties: Viable in 50 per cent glycerine at 2° C at least 5 weeks, in 50 per cent glycerine at 10° C. at least 7 weeks, dried while frozen at least 7 weeks, in frozen saliva at least 3 weeks.

Literature: Bloch, Am. Jour. Path., *13*, 1937, 939–944; Enders and Cohen, Proc. Soc. Exp. Biol. and Med., *50*, 1942, 180–184; Findlay and Clarke, Brit. Jour. Exp. Path., *15*, 1934, 309–313; Johnson and Goodpasture, Jour. Exp. Med., *59*, 1934, 1–19; Am. Jour. Hyg., *21*, 1935, 46–57; *23*, 1936, 329–339; Am. Jour. Path., *12*, 1936, 495–510.

2. **Rabula levis** *spec. nov.* From Latin *levis*, trifling.

Common name: Guinea-pig salivary-gland virus.

Host: *CAVIIDAE—Cavia porcellus* (L.), guinea pig (only known host; fetus more susceptible than post-natal animal, even if from immune mother).

Insusceptible species: Rabbit, rat, cat, chicken, pigeon, dog, mouse, monkey (*Macacus rhesus*).

Geographical distribution: United States, England.

Induced disease: In guinea pig, submaxillary glands show swollen epithelial cells containing relatively dense acidophilic inclusions of granular material within enlarged nuclei, especially in ducts of the serous portion of the gland, and larger but fewer intracytoplasmic inclusions; experimentally, by intracerebral injection of young guinea pig, prodromal period of about 2 days, then elevation of temperature to 105 or 106° F; a day later, hair raised, animal quiet; subsequently, irritability with tremors and slight convulsive movements; by fifth day, usually prostration, jerking movements, and ensuing death; brain shows no gross lesions but exudate over surface; in meningeal exudate, many cells each containing an acidophilic mass within its nucleus; by subcutaneous injection, virus recoverable after 2 weeks from submaxillary glands, cervical lymph nodes, kidney, and lung, not from blood, liver, or spleen.

Transmission: Experimentally, by inoculation of submaxillary gland or by intracerebral or subcutaneous injection of materials from infected glands; with difficulty from brain to brain. Pilocarpine stimulation increases numbers of inclusions.

Serological relationships: Specific neutralizing antibody is found in blood serum of animals that are carrying virus in their submaxillary glands.

Immunological relationships: Active immunity may be dependent on existence of more or less active lesions.

Thermal inactivation: At 54° C in 1 hour.

Filterability: Passes Berkefeld N filter candle.

Other properties: Viable in 50 per cent glycerine at least 11 days.

Strains: An unusually virulent strain, killing infected animals whatever the route of injection, has been described but not given a distinctive name (Rosenbusch and Lucas, Am. Jour. Path., *15*, 1939, 303–340).

Literature: Andrewes, Brit. Jour. Exp. Path., *11*, 1930, 23–34; Cole and Kuttner, Jour. Exp. Med., *44*, 1926, 855–873; Hudson and Markham, *ibid.*, *55*, 1932, 405–415; Jackson, Jour. Inf. Dis., *26*, 1920, 347–350; Kuttner, Jour. Exp. Med., *46*, 1927, 935–956; Kuttner and T'ung, *ibid.*, *62*, 1935, 805–822; Lucas, Am. Jour. Path., *12*, 1936, 933–948; Markham, *ibid.*, *14*, 1938, 311–322; Markham and Hudson, *ibid.*, *12*, 1936, 175–182; Pearson, *ibid.*, *6*, 1930, 261–274; Scott, Jour. Exp. Med., *49*, 1929, 229–236; Scott and Pruett, Am. Jour. Path., *6*, 1930, 53–70.

3. **Rabula innocuus** *spec. nov.* From Latin *innocuus*, harmless.

Common name: Hamster salivary-gland virus.

Host: *CRICETIDAE—Cricetulus griseus* M. Edw., Chinese hamster.

Insusceptible species: *MURIDAE*—rat; *Mus musculus* L., white mouse.

Geographical distribution: China.

Induced disease: In hamster, no obvious disease externally but inclusion bodies in submaxillary glands.

Thermal inactivation: At 56° C in 30 minutes.

Literature: Kuttner and Wang, Jour. Exp. Med., *60*, 1934, 773-791.

4. **Rabula exiguus** *spec. nov.* From Latin *exiguus*, petty.

Common name: Rat salivary-gland virus.

Host: *MURIDAE*—rat.

Insusceptible species: *MURIDAE—Mus musculus* L., mouse. *CRICETIDAE—Cricetulus griseus* M. Edw., Chinese hamster.

Geographical distribution: China, Canada.

Induced disease: In rat, no obvious disease externally, but intranuclear inclusions in cells of the submaxillary glands.

Literature: Kuttner and Wang, Jour. Exp. Med., *60*, 1934, 773-791; Thompson, Jour. Inf. Dis., *50*, 1932, 162-170.

5. **Rabula latens** *spec. nov.* From Latin *latens*, hidden or lurking.

Common name: Mouse salivary-gland virus.

Host: *MURIDAE—Mus musculus* L., mouse.

Insusceptible species: *MURIDAE*—rat. *CRICETIDAE—Cricetulus griseus* M. Edw., Chinese hamster. *LEPORIDAE*—rabbit. *CAVIIDAE—Cavia porcellus* (L.), guinea pig.

Geographical distribution: China, Canada, United States.

Induced disease: In mouse, no obvious disease externally, but inclusion bodies in acinar tissue of serous and mucous portions of submaxillary glands; occasionally also in duct cells or alveolar cells of parotid gland; affected cells hypertrophied. In Swiss white mice, extensive lesions in liver and spleen but emulsions of these organs fail to infect; rare pancreatic lesions.

Transmission: Experimentally, by intraglandular, subcutaneous, intraperitoneal, intratesticular or intracerebral inoculation; inclusion bodies appear in salivary glands irrespective of site of inoculation.

Thermal inactivation: At 60° C in 30 minutes.

Filterability: Passes Berkefeld V filter candle.

Literature: Kuttner and Wang, Jour. Exp. Med., *60*, 1934, 773-791; McCordock and Smith, *ibid.*, *63*, 1936, 303-310; Thompson, Jour. Inf. Dis., *58*, 1936, 59-63

SUPPLEMENT NO. 3

PLEUROPNEUMONIA AND PLEUROPNEUMONIA-LIKE ORGANISMS (BORRELOMYCETACEAE)

Louis Dienes

Boston, Mass.

May, 1945

THE ORGANISM OF CONTAGIOUS BOVINE PLEURO-PNEUMONIA AND RELATED ORGANISMS*

INTRODUCTION

The organism of bovine pleuropneumonia is similar in certain respects to filterable viruses. Both in infected tissue and in cultures, small elements are present which pass through filters that retain bacteria. The organism is not stained well by the usual bacterial stains and can be made visible only by using special methods. Bovine pleuropneumonia and other diseases caused by similar organisms were originally attributed to filterable viruses. These organisms are different from viruses in an important point; namely, they grow on suitable media in the absence of living host cells. The cultures consist of pleomorphic elements, the nature of which has only slowly become apparent. By the studies of Nowak (Ann. Inst. Past., *43*, 1929, 1330), Turner (Jour. Path. and Bact., *41*, 1935, 1) and Klieneberger and Smiles (Jour. Hyg., *42*, 1942, 110), it has been established that the pleomorphic forms are part of a reproductive cycle different from binary fission. The small elements in the cultures swell up into large round forms which reproduce the small elements within their membranes. The morphology of the organism is further complicated by the fact that long branching filaments are present in freshly isolated bovine strains. These break up into granules or parts of the filaments swell up into large round forms. In the judgment of some investigators, these properties, in addition to unusual softness and fragility, exclude the organism of bovine pleuropneumonia and similar organisms from the order of true bacteria. Ledingham (Jour. Path. and Bact., *37*, 1933, 393) has classified them with the *Actinomyces*. Later, Turner (Jour. Path. and Bact., *41*, 1935, 1) placed them in an independent order, *Borrelomycetales*, while Sabin (Bact. Rev., *5*, 1941, 58) has even placed them in an independent class, *Paramycetes*.

The observations of the present author give support to the classification of Buchanan (Jour. Bact., *3*, 1918, 44) who placed the genus *Asterococcus* Borrel et al. with the organism of bovine pleuropneumonia (*Asterococcus mycoides* Borrel et al.) as type, together with the genus *Haemophilus* Winslow et al. in subtribe *Haemophilinae* Buchanan of the tribe *Bacterieae* Trevisan emend. Buchanan. In many strains of the pleuropneumonia

*Common names have been used through Supplement No. 3 (except for *Asterococcus* and *A. mycoides*) as the author believes that a more suitable nomenclature than any thus far proposed should be developed when agreement is reached as to the nature of these organisms. Specific names that have been proposed are given merely as a matter of record. No new names have been introduced.

group, the small forms appear in appropriate preparations as small bipolar stained bacilli. The transformation of the bacilli to round bodies of variable size often occurs in bacterial cultures and is not specific for the pleuropneumonia group. Furthermore, it has been observed in several species of bacteria that they reproduce in the large round forms in a manner similar to that observed in the pleuropneumonia group. Thus the form variation and reproductive processes observed in the pleuropneumonia group are not specific to this group. They represent general bacterial properties and should be included in the definition of the true bacteria.

According to these considerations, the organisms belonging to the pleuropneumonia group are small, Gram-negative bacilli often showing bipolar staining and their distinctive characteristic is the tendency to swell up into round forms and multiply by the reproduction of bacilli in the round forms. Their habitat is in the mucous membranes of animals and man and many of them are pathogenic. They are exacting in their media requirements and usually require fresh animal serum for their growth. These properties indicate a close similarity to the species now included in the genera *Pasteurella* and *Haemophilus*. The pleuropneumonia group might well be classified in the same or a closely related family. It is uncertain whether the strains isolated from earth and sewage should be classified with the strains isolated from animals and men. The soil and sewage strains are less soft, stain more easily and grow abundantly without animal serum. The strains isolated from bacterial cultures are most probably variant forms of the bacteria and should be classified with the parent organisms.

The viruses of psittacosis and lymphogranuloma present similarities to the pleuropneumonia group both in morphology and in their methods of reproduction. This gives added weight to the thought that the pleuropneumonia group represents an intermediary stage in the evolution of the small, Gram-negative bacteria of the mucous membranes into the filterable viruses.

I. THE PLEUROPNEUMONIA GROUP.

(*Borrelomycetaceae* Turner, Jour. Path. and Bact., *41*, 1935, 25; *Parasitaceae* Sabin, Bact. Rev., *5*, 1941, 58.)

The organisms are soft and fragile. Without special precautions they are often distorted or entirely destroyed in microscopical preparations. The cultures contain pleomorphic elements: Small granules, bacilli, bacillary filaments and round forms varying in size from a few tenths of a micron to 10 microns or more. Autolyzed round forms may coalesce into large empty blebs. The round forms are part of a reproductive cycle. They are produced by the swelling of the bacillary forms and filaments and reproduce granules or filaments by inside segmentation or multiple germination. In freshly isolated bovine strains, the filaments show apparent or true branching and reproduce the small forms by segmentation. The smallest growing units may not be larger than .15 to .28 micron and pass through filters that retain bacteria. On agar, tiny colonies (0.1 to 0.6 mm) develop in great numbers. The colonies invade the agar and after 2 to 5 days growth have an opaque center embedded in the agar and a thin peripheral zone. The surface has a rugged or granular appearance due to the development and autolysis of the large forms. After a few days growth, the cultures usualy show pronounced autolysis. The parasitic strains require fresh animal serum for growth. There is a single genus.

Genus I. **Asterococcus** *Borrel et al.*

(Borrel, Dujardin-Beaumetz, Jeantet and Jouan, Ann. Inst. Past., *24*, 1910, 179; *Coccobacillus* Martzinovski, Ann. Inst. Past., *25*, 1911, 91; *Micromyces* Frosch, Arch. f. wissensch. u. prakt. Tierheilk., *49*, 1923, 35 and 273; not *Micromyces* Dangeard, Le Botaniste, *1*, 1888, 55; *Mycoplasma* Nowak, Ann. Inst. Past., *43*, 1929, 1349; *Asteromyces* Wroblewski, Ann. Inst. Past., *47*, 1931, 105; *Borrelomyces* Turner, Jour. Path. and Bact., *41*, 1935, 25; *Bovimyces* Sabin, Bact. Rev., *5*, 1941, 57.)

Characters as for the family.

The type species is *Asterococcus mycoides* Borrel et al.

1. **Asterococcus mycoides** Borrel et al. (Le microbe de la péripneumonia, Nocard and Roux, Ann. Inst. Past., *12*, 1898, 240; Borrel, Dujardin-Beaumetz, Jeantet and Jouan, Ann. Inst. Past., *24*, 1910, 168; *Coccobacillus mycoides peripneumoniae* Martzinovski, Ann. Inst. Past., *25*, 1911, 914; *Micromyces peripneumoniae bovis contagiosae* Frosch, Arch. f. wissensch. u. prakt. Tierheilk., *49*, 1923, 35 and 273; *Mycoplasma peripneumoniae* Nowak, Ann. Inst. Past., *43*, 1929, 1530; *Asteromyces peripneumoniae bovis* Wroblewski, Ann. Inst. Past., *47*, 1931, 94; *Borrelomyces peripneumoniae* Turner, Jour. Path. Bact., *41*, 1935, 1; *Bovimyces pleuropneumoniae* Sabin, Bact. Rev., *5*, 1941, 57.)

Morphology of cells and appearance of agar cultures correspond with the description given for the group.

Broth cultures are slightly opalescent and, upon shaking, the cultures of fresh strains exhibit silk-like whorls, due to the presence of long chains and filaments. The cultures after prolonged incubation consist of small granules.

Biochemical activity: Old colonies on serum agar develop a brownish color. Freshly isolated strains reduce hemoglobin. Glucose, fructose, mannose, maltose, and dextrin are fermented with the production of acid but no gas. The cultures are bile soluble.

The strains isolated from cattle are homogeneous in serological reactions and distinct from the other members of the group.

Habitat: It is the causative agent of contagious bovine pleuropneumonia. The disease can be transferred to sheep, goats and water buffaloes, but not to mice, rats, rabbits or other experimental animals.

2. **The organism of agalactia of sheep and goats.** (Le microbe d'agalaxie contagieuse, Bridré and Donatien, Ann. Inst. Past., *39*, 1925, 925; *Anulomyces agalaxiae* Wroblewski, Ann. Inst. Past., *47*, 1931, 111; *Borrelomyces agalactiae* Turner, Jour. Path. and Bact., *41*, 1935, 25; *Capromyces agalactiae* Sabin, Bact. Rev., *5*, 1941, 57.)

These organisms are very similar to the former organisms in morphology, appearance of the cultures and growth requirements. Usually the growth is less vigorous, the colonies remain smaller, and the elements of the cultures are more delicate and less easily visible than those of bovine pleuropneumonia. Characteristic crystals develop in the cultures.

Serologically and immunologically this species is distinct from the bovine species.

It is the cause of a systemic disease in sheep and goats with involvement of the joints, eyes, and, in lactating animals, the mammary glands. Other species are not susceptible.

3. **Pleuropneumonia-like organisms in dogs.** (*Asterococcus canis*, Types I and II, Schoentensack, Kitasato Arch. Exp. Med., *11*, 1904, 227; *13*, 1936, 175; *Canomyces pulmonis* I and II, Sabin, Bact. Rev., *5*, 1941, 57.)

Both types produce slight uniform opalescence in broth. Type I grows in granules and coarse colonies and is apparently pathogenic for dogs. Type II grows in somewhat larger granular colonies.

They are serologically distinct from each other and from the other members of the pleuropneumonia group.

The connection of these organisms with distemper is not proven.

4. **Pleuropneumonia-like organisms in rats.** L_3 (Klieneberger and Steabben, Jour. Hyg., *37*, 1937, 143; Jour. Hyg., *40*, 1940, 223; *Murimyces pulmonis* Sabin, Bact. Rev., *5*, 1941, 57.)

L_4 (Klieneberger, Jour. Hyg., *38*, 1938, 458; *Murimyces arthritidis* Sabin, *loc. cit.*)

The pyogenic virus of Woglom and Warren (Jour. Exp. Med., *68*, 1938, 513) and L_7 of Findlay, MacKenzie, MacCallum and Kleineberger (Lancet, *237*, 1939, 7) are identical with L_4. The organisms isolated from infected joints by Beeuwkes and Collier (Jour. Inf. Dis., *70*, 1942, 1) and Preston (*ibid.*, *70*, 1942, 180) probably are identical with L_4 but they were not typed serologically.

The requirements for growth, the appearance of colonies and the morphology are very similar to those of the type strain with the difference that long filaments are not observed either in liquid or solid media.

The strains isolated from rats belong to two serological types. L_3 was cultivated from chronic lung abscesses, but the number of strains typed is not sufficient to ascertain that all strains isolated from this source belong to one type. The L_3 strains are not pathogenic for rats in artificial infection. They produce suppuration in mice when they are injected with agar.

L_4 which is serologically different from L_3 was cultivated from abscesses and spontaneous polyarthritis. It produces polyarthritis both in mice and rats. It is not infectious in monkeys, rabbits and guinea pigs. Both L_3 and L_4 were recovered from the brains of mice kept in the same room with rats.

According to Klieneberger, L_3 usually produces somewhat larger and coarser colonies than L_4; L_3 grows in broth in small granules, while L_4 produces an opalescent growth.

5. Pleuropneumonis-like organisms in mice. (Sabin, Science, *88*, 1938, 575, and Bact. Rev., *5*, 1941, 1; Findlay, Klieneberger, MacCallum and MacKenzie, Lancet, *235*, 1938, 1511.) A strain isolated by Sullivan and Dienes (Proc. Soc. Exp. Biol. and Med., *41*, 1939, 620) is identical with Type A.

Five groups of strains, distinct serologically, and, to a certain extent, distinct also in their pathological properties, have been isolated from mice. These are types A, B, C, D, and E of Sabin. The strains are closely similar to each other and to the rat strains. It is questionable whether the slight differences in the appearance of the colonies and in the morphology of the cultures are of significance.

Type A (*Musculomyces neurolyticus* Sabin) is usually present in the conjunctiva and was isolated also from the lung and brain. Intercerebral injection of Type A produces in mice a characteristic rolling disease due to a toxin which is also present in broth cultures. Intravenous injection produces a transient polyarthritis without damage to the cartilage or ankylosis. Type A is serologically similar to L_5 of Klieneberger, (Jour. Hyg., *40*, 1940, 204).

Type B (*Musculomyces arthrotropicus* Sabin) was isolated from the brain and from the nasal mucosa. It produces no rolling disease and no soluble toxin. In mice, intravenous injection usually produces a chronic arthritis often leading to ankylosis.

Types C, D and E (*Musculomyces histotropicus* Sabin) were isolated from the same location as Type B and produce similar arthritic lesions. They are serologically distinct from Type B and from each other (Sabin, Science, *90*, 1939, 18 and Sabin and Johnson, Proc. Soc. Exp. Biol. and Med., *44*, 1940, 569).

L_6 isolated from mice by Findlay et al. (Trans. Roy. Soc. Trop. Med. Hyg., *33*, 1939–40, 6) and the strains of Edward (Jour. Path. and Bact., *50*, 1940, 409) were not compared serologically with the types of Sabin.

6. Pleuropneumonia-like organisms in man. (Dienes, Proc. Soc. Exp. Biol. and Med., *44*, 1940, 468; Beveridge, Med. Jour. of Australia, *30*, 1943, 479; Kleineberger, Lancet, *2*, 1945, 46.)

They are present in about 30 per cent of women in the genitals and they were isolated from suppurative processes originating from this source. In men they were found in urethritis, cystitis and chronic prostatitis.

The appearance of the colony, the morphology and growth requirements correspond with the animal strains. The human strains grow less abundantly in serum broth than the animal strains.

One strain was found by Sabin (Proc. Soc. Exp. Biol. and Med., *44*, 1940, 569) to be serologically different from the strains isolated from rats and mice. It is not known whether the strains are serologically uniform. There is a slight variation in colony form, in the tendency to grow in filaments, and in the abundance of growth, but the variation between the strains is less than the variation due to slightly different cultural conditions.

Mice and rats are usually not susceptible to infection with the human strains; however, several young mice from a single litter were killed in three to six days by subcutaneous or intraperitoneal injection of one strain.

7. Pleuropneumonia-like organisms in chick embryos. (Van Herick and Eaton, Jour. Bact., *50*, 1945, 47.)

Organisms have been isolated from chick embryos which conform to the pleuropneumonia group with regard to morphology, the appearance of colonies on agar and filterability. The cultures agglutinated red blood cells from various animals. The relation of this strain to the coccobacillary bodies of Nelson (see Section II) has not been studied.

II. ORGANISMS OF UNCERTAIN CLASSIFICATION.

Similar to the Pleuropneumonia Group.

1. **Coccobacillary bodies of Nelson.** (Nelson, Science, *82*, 1935, 43; Jour. Exp. Med., *65*, 1937, 833; Jour. Exp. Med., *72*, 1940, 615.)

Nelson isolated a small bacillary organism apparently connected with coryza and infectious catarrh from the nasal passages of fowls and from the nasal passages and the middle ear of mice and rats. Their size appeared to be 0.3 to 0.4 micron in microscopical preparations and they passed through a filter with a pore size of 640 millimicrons. They were isolated in tissue cultures but they grow also in the cell-free and heated supernatant fluid. The freshly isolated cultures did not grow on blood or on artificial media; however, after 120 passages in tissue cultures the fowl coryza bodies grew on blood agar slants. On ascitic agar this strain forms colonies very similar to those of the pleuropneumonia group with a dark center surrounded by a thin periphery. The organisms in the top layer are sometimes considerably enlarged, but no web-like structure is produced. The organism is less soft and the individual organisms maintained their form in the preparations as do bacteria, and the tendency to grow into the agar is less pronounced than in the pleuropneumonia group. The organism isolated from rats is more pleomorphic than the others.

The coccobacillary bodies were not studied with methods appropriate to determine whether they belong to the pleuropneumonia group and whether the mouse and rat strains are identical with the pleuropneumonia-like organisms isolated from mice and rats.

2. **Filterable organisms from sewage and soil.** (Fam. *Saprophytaceae* Sabin, Genus *Sapromyces* Sabin, Bact. Rev., *5*, 1941, 59.)

The strains isolated by Laidlaw and Elford (Proc. Roy. Soc. London, B, *120*, 1936, 292; *Sapromyces laidlawi A B* and *C*, Sabin, *loc. cit.*) and Seiffert (Cent. f. Bakt., I Abt., Orig., *139*, 1937, 337) according to Ørskov (Cent. f. Bakt., I Abt., Orig., *141*, 1938, 230) and Klieneberger (Jour. Hyg., *40*, 1940, 204) are closely similar to the organisms of the pleuropneumonia group. They are filterable, and the smallest reproductive units of those which we have appropriately examined were found to be between .125 and .175 micron. The colonies are similar in appearance to the colonies of the pleuropneumonia group.

The broth cultures consist of granules and round globular elements; the surface layer of agar colonies sometimes swells up into large round forms. They grow without serum, but small amounts of serum accelerate the growth. They grow both at 30° and at 37°C. and remain alive in cultures kept cold for several months. The broth cultures grow abundantly with a strong opalescence or sediment. Serologically the strains are distinct from the other members of the pleuropneumonia group and all but one are more or less similar to each other.

III. PLEUROPNEUMONIA-LIKE ORGANISMS ISOLATED FROM BACTERIAL CULTURES.

1. **Pleuropneumonia-like organisms isolated from Streptobacillus moniliformis.** L_1 (Klieneberger, Jour. Path. and Bact., *40*, 1930, 93; Jour. Hyg., *42*, 1942, 485; Dienes, Jour. Inf. Dis., *65*, 1939, 24; Jour. Bact., *44*, 1942, 37; *Musculomyces streptobacilli-moniliformis* Sabin, Bact. Rev., *5*, 1941, 57; Heilman, Jour. Inf. Dis., *69*, 1941, 32; Brown and Nunemaker, Bull. Johns Hopkins Hosp., *70*, 1942, 201.)

Cultures isolated from different strains

of *Streptobacillus moniliformis* vary considerably in the appearance of the colonies, the tendency to reversion to bacillary form, and the degree of autolysis. The colonies are considerably larger than the colonies of the human or animal pleuropneumonia-like strains; they may reach 1 to 2 mm. Usually a wide peripheral zone is present and development and autolysis of the large bodies produces a coarse appearance in the colonies. Sometimes no peripheral zone develops, the colony is dome-shaped, and the large bodies have no tendency to autolyze. The young colonies (twelve hours incubation) grow into the agar as loose strands of more or less swollen granules. Serum broth cultures grow in small clumps usually adhering to the wall of the test tube.

The cultures consist of small granules, small polar-staining bacilli and diphtheroid-like forms which swell to large round forms. In the top layer of fully developed colonies, the well-stained large bodies may be as large as 10 to 20 microns. By vacuolization they transform into empty blebs. By segmentation of their contents, the large forms may reproduce the small bacillary forms. In suitable preparations chromatin bodies are visible both in the small and large forms. The small forms are filterable through Berkfeld candles; the size of the smallest particles has not been exactly determined. The organism is very soft and fragile.

Their growth requirements and biochemical activities are similar to those of *Streptobacillus moniliformis*.

Growth occurs on nutrient agar containing animal serum or egg yolk. Sometimes there is a slight growth on boiled blood agar plates without serum. Good growth is obtained in a mineral solution with 0.1 per cent starch. Growth is both aerobic and anaerobic.

The L_1 form is more resistant to heat and to aging of the culture than is the streptobacillus and it has a remarkable resistance to penicillin to which the bacteria are very sensitive. Like the bacillus, L_1 produces acid but no gas from glucose, maltose, fructose, salicin, starch, and dextrin. It gives no oxidase test.

Serologically the L_1 form is similar to *Streptobacillus moniliformis* and different from the members of the pleuropneumonia group. It has no pathological effect on mice, rats or guinea pigs. It does not produce an infection of the chicken embryo. It can be isolated from freshly isolated strains of *Streptobacillus moniliformis*, from several-day old broth and agar cultures, from broth cultures heated at 56°C. and usually also from 48 hour agar cultures if they are incubated at 28° to 30°C. It is questionable whether the L_1 form has been isolated directly from rats.

Klieneberger (Jour. Hyg., *40*, 1940, 204) isolated a similar strain from a bacterium similar to *Streptobacillus moniliformis* which caused abscesses in guinea pigs. Whether this bacterium was identical or different from *Streptobacillus moniliformis* was not determined.

2. **Pleuropneumonia-like organisms isolated from Bacteroides funduliformis.** Dienes (Proc. Soc. Exp. Biol. and Med., *47*, 1941, 385) and Dienes and Smith (Jour. Bact., *48*, 1944, 125) isolated cultures from two strains of *Bacteroides funduliformis* which could be propagated indefinitely and which in morphology and in the appearance of colonies were closely similar to L_1.

The young colonies consisted of similar strands of granules growing into the medium. The surface of fully developed colonies consisted of large bodies and a honey-comb-like structure. The well isolated colonies grew usually to a fairly large size (1 to 2 mm).

Both strains, transplanted every two or three days through several months, failed to reproduce bacteria either on agar or submerged in broth.

No growth was obtained in liquid cultures.

The strains, like the parent organism, are strictly anaerobic and the cultures have the characteristic odor of the parent strain.

It was observed in slide cultures that the L type of colonies develop from large round forms which were produced in the cultures of the parent organism by gradual swelling of the bacteria.

In cultures of eight pleomorphic strains of *Bacteroides*, the L type of colonies developed in three strains under appropriate conditions. The bacteria swelled into large round bodies in all eight strains. The serological properties of the L strains have not thus far been studied. Neither the parent organisms nor the L type strains had any pathological effect on laboratory animals.

3. **Pleuropneumonia-like organisms in a species of Flavobacterium.** (Dienes, Jour. Bact., *44*, 1942, 37.)

Tiny colonies entirely similar in appearance to young L_1 colonies were isolated from the cultures of a species of *Flavobacterium*.

The bacterium when freshly isolated produced two types of colonies on blood agar plate; large colonies consisting of small regular bacilli and tiny colonies in which the bacteria became pleomorphic and swelled up to form large round bodies. The tiny colonies after 48 hours of incubation became autolyzed, and one or several L type of colonies started to grow under them. These colonies could be transplanted and gave abundant growth for two generations, but always died out in the third.

Bacterial forms were not reproduced either on agar or in broth.

The L type of growth was not pathogenic for mice though the parent organism was highly virulent.

4. **Development of tiny colonies in other bacteria.**

The development of tiny colonies similar in appearance to young colonies of the pleuropneumonia group has been observed in cultures of *Escherichia coli*, *Haemophilus influenzae*, and *Neisseria gonorrhoea* (Dienes, Jour. Bact., *44*, 1942, 37; Proc. Soc. Exp. Biol. and Med., *44*, 1940, 476). In all cases preceding their development, the organisms of the parent strains swelled into large round bodies, and in *Escherichia coli* and *Haemophilus influenzae* the development of the L type of colonies from these large forms was observed. Thus far these tiny colonies have not been isolated in pure cultures.

INDEX*

SOURCES AND HABITATS

(All references to viruses will be found under the heading †Viruses)

*Prepared by Prof. Robert S. Breed and Mrs. Margaret E. Breed, Geneva, New York, August, 1947.

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INDEX OF THE NAMES OF GENERA AND SPECIES*

(For Index of the Names of Orders, Families, Genera and Groups of Intermediate Rank, See Table of Contents, p. XI.)

*Index prepared by Prof. Robert S. Breed and Mrs. Margaret E. Breed, New York State Experiment Station, Geneva, New York, June, 1947.